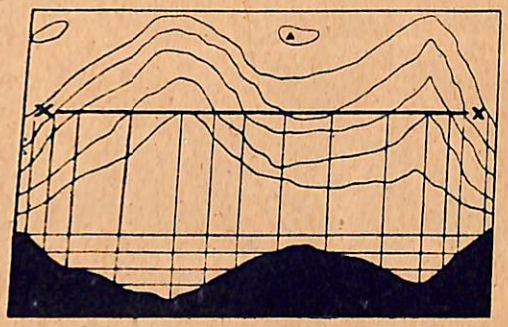
MAP READING



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MAP READING MADE EASY

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BY

CAPT. C. C. ESSON

AND

G. S. PHILIP, F.R.G.S.

SEVENTH EDITION

AMENDED FOR USE IN CONJUNCTION WITH THE
"MANUAL OF MAP READING, PHOTO READING AND FIELD SKETCHING"
AT THE ROYAL MILITARY COLLEGE

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PREFACE

EVERYONE—man, woman, boy and girl ought to be able to read a map correctly and quickly. An experienced map reader can visualise the country shown on a map—the heights, valleys, nature of the country, etc.; can measure directions, slopes, and distances; and can gauge the suitability of different parts for different objects; and, in addition, he is master of the innumerable details shown by the conventional signs on the map.

That Map Reading has been strangely neglected in this country is a fact which was brought home forcibly by the war to thousands of men who, before they could become Officers or efficient N.C.O.'s or soldiers, found that they had to be proficient in this subject.

The present work is primarily intended for use in schools, and it is hoped that it will enable the geographical instruction already given to be made use of in such a way that the study of the map for practical purposes may be stimulated.

Further, such subjects as arithmetic, geometry, and drawing will be found intimately associated with Map Reading and its problems.

The treatment of the Relief of the Surface has received special attention, since it is only through a thorough knowledge of the various methods by which such relief is represented that a proper understanding of a map can be obtained. For example, when using a map for the purpose of finding the best way of reaching a particular place, the direction of the route and the distance travelled are largely dependent upon the nature of the surface of the intervening country. These are matters that can only be determined by a competent map reader. Again, every river, road, railway, and canal on the map owes its position to the natural configuration of the surface and to a large extent so do the woods, the forests, and the cultivated areas; the position of the market towns, seaports, and industrial centres are equally dependent upon the same natural conditions.

Geography properly understood is intimately associated with almost every branch of knowledge, and therefore possesses an essentially educational value. It goes without saying that the basis of all geographical teaching should be the proper understanding of the map, which hitherto, unfortunately, has not always been the case.

It is claimed for this work that the novice will be able to understand it without difficulty, as it is assumed throughout that the reader has no previous knowledge of the subject.

A special feature of the book is the large number of diagrams and maps, which should greatly facilitate description and understanding.

The endeavour has been to show the "Why and the Wherefore" of everything, rather than to give definitions and formulæ to be remembered.

The *Contour Book** and *Junior Contour Book** by Ernest Young, B.Sc. and J. Fairgrieve, M.A., provide numerous practical exercises and problems for class use, and will be found to form most useful companion books to Part I of the present work. There is also a book "*Contours*"* by Boxhall and Devereux, which we recommend and which has many clear and excellent illustrations. Another extremely useful work is "*The Interpretation of Ordnance Survey Maps and Geographical Pictures*"* by Lockey containing photographs and Ordnance Survey maps.

The authors are indebted for the use of the following blocks and illustrations to Major A. D. St. G. Bremner, M.C., Royal Engineers, for Figs. 40, 43, 88, 91, 92, 96 and 100 from *The Prismatic Compass and How to Use it*, published by E. R. Watts and Son; to Messrs. W. F. Stanley & Co. Ltd. for Fig. 22; to the Controller of H.M. Stationery Office for Figs 1, 3, 107 and 136, and page 82.

*All published by George Philip & Son. Ltd.

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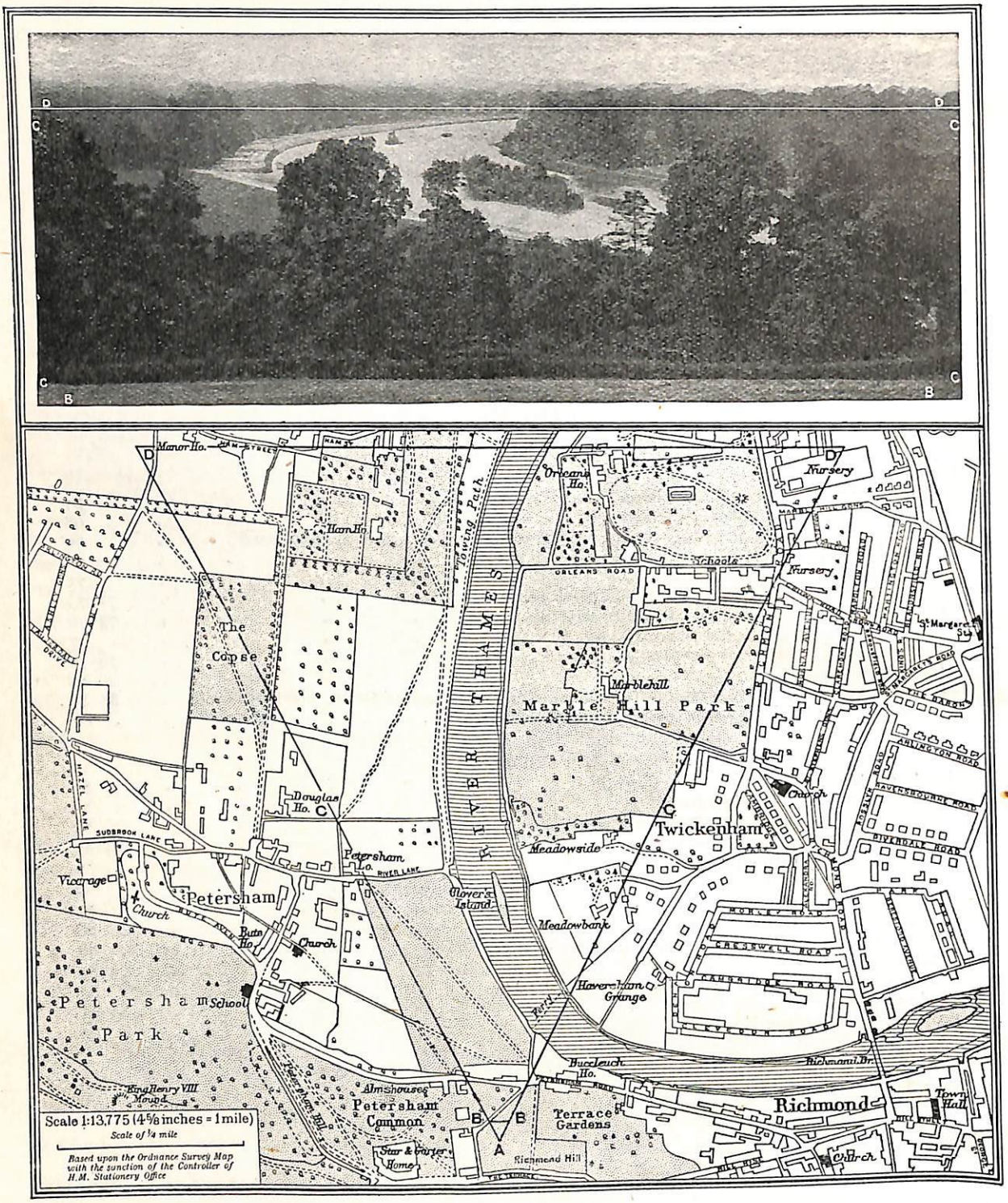


Fig. 1. Comparison between Picture and Map

A. Position of Observer. *B B*. Foreground of the Picture. *C C*. Limits of the View left and right. The white line *D D* on the Picture shows the limit to which the map extends.

INTRODUCTION

What a Map is. A map is a reproduction or picture of some portion of the earth's surface, but it differs materially from an ordinary picture for two reasons:

1. Whereas in an ordinary picture objects are represented as seen from a point on the ground and are reproduced as they appear to the observer at a comparatively short distance, in a map objects are represented as they would appear if seen from a great height, such as would be obtained by an observer in an aeroplane. In this way the extent of country which can be reproduced on a map is naturally very much greater than the area which can be covered by any one picture or photograph. (Fig. 1.) As will be seen by looking at a photograph taken from an aeroplane, all objects appear to be on the same level and all differences in height such as are caused by hills and valleys entirely disappear.
2. In an ordinary picture all objects are represented so as to be easily recognizable at a glance, whereas in a map everything must either be named or marked with a distinguishing symbol.
   These symbols vary for different kinds of maps and for different countries, but in order to understand any particular map it is necessary to learn the meaning of the symbols used to represent the objects shown on the map.
   These symbols may be regarded as the alphabet of map reading and when once properly understood they enable anyone when looking at a map to form a picture of the country it represents, just as the printed notes on a sheet of music convey to the brain of a musician all the infinite variety of sounds which are contained in any musical composition.
   The nearer the size of the map corresponds with the country it represents the more realistic it can be made and the greater the number of symbols that can be made use of.

Conventional Signs. In order to avoid confusion every country has arranged map symbols into a regular system known as Conventional Signs, and in this country the system universally adopted for all large Scale maps is that of the Ordnance Survey. For Military maps and sketches slight modifications of and additions to the Conventional Signs have been introduced in order to emphasize features of special interest for military purposes.

Conventional Signs may be divided into two classes:

1. Those designed to represent natural features such as hills, valleys, woods, rivers, etc.
2. Those designed to represent artificially made features such as towns, buildings, roads, railways, canals, etc. Illustrations of these signs will be found on pages 3, 4, and 5.

Relief of the Surface. By far the most important of the Conventional Signs are those by which the actual surface of the land is represented, as they enable one to form a mental picture of what the ground is really like with its hills and valleys, ridges, slopes, and plains. In this connection contours and the measurement of slopes are dealt with.

Direction. Next in importance is the knowledge of how to set a map, that is to place it in such a position on the country it represents that the direction of any feature on the map corresponds with the direction of the same feature in the actual country. Until a knowledge of how this can be done has been obtained it is difficult to identify any object in the country with the symbol representing it on the map.

In connection with this, a knowledge of Bearings, the Compass, and the Protractor are essential to a map reader. Each of these is explained very fully and in the most simple language possible.

Distance. Every map is so drawn that its size bears a definite relationship to the size of the country it represents, and a knowledge of how this relationship is expressed must be obtained in order to measure the actual distances between any points on the map. The construction and use of scales fall under this heading.

From the foregoing it will be seen that the study of Map Reading falls naturally into three divisions:

1. Relief of the Surface.
2. Direction.
3. Distance.

And this order has been followed in the present work.

The Curvature of the Earth's Surface. We commenced by saying that a map is a reproduction of some portion of the earth's surface, and we must now point out one of the greatest difficulties with which the map maker has to contend and with which everyone who uses a map should be familiar. The difficulty is that whereas the surface of the earth is curved, a map must be drawn on a flat piece of paper, and it is no more possible to represent a curved surface on a flat plane without distortion of some kind than to take half the rind off an orange, and flatten it out without splitting it somewhere. The larger the area the greater the distortion would be.

It is therefore impossible to construct a map on a flat piece of paper which is a perfectly accurate representation of any portion of the earth's surface, but the smaller the area mapped the less will be the amount of distortion.

Fig. 2 shows the parallels of latitude and meridians or circles of longitude by means of which the exact position of any particular spot on the surface of the globe can be accurately determined, and it would be possible to make a map by fixing the positions of the principal points by means of their latitude and longitude drawing in the minor details by measurement from these points. Such a map would, however, not be sufficiently accurate to be of very much use.

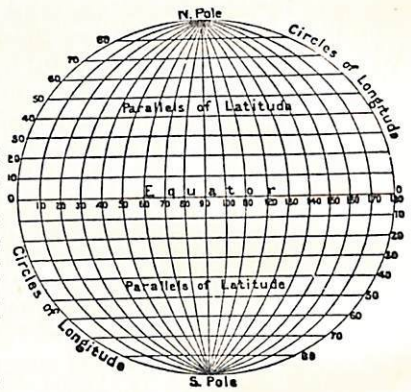


Fig. 2

An explanation of how to construct an accurate map would involve a description of the various methods by which it is possible to project a curved object on to a flat surface with the minimum of distortion. Such an explanation does not come within the scope of this manual, and it must suffice to state that the survey maps prepared by our own and foreign Governments which form the basis of all maps in general use are so constructed that the errors caused by the inevitable distortion are practically eliminated.

In the case of the British Ordnance map the error at a distance of 150 miles from the meridian of longitude in the centre of the map does not exceed one in a thousand.

So that for all practical requirements of map reading it may be laid down:

1. That all objects on the map are in the same relative positions as on the ground.
2. All angles between lines drawn on this map are equal to angles between corresponding lines drawn on the ground.

Use of Maps in the Great War. To show how universally maps were required in every branch of the Army, we give a list of some of the special maps used in addition to the ordinary topographical ones:—*Enemy Order of Battle Maps, Enemy Organisation Maps, Trench Maps, Railways Maps, Road and Bridge Maps, Traffic Maps, Barrage Maps, Geological Maps, Water Supply Maps. Message Maps, Administrative Maps and Aeroplane Photo Maps.*

SOME CONVENTIONAL SIGNS ON ORDNANCE MAPS

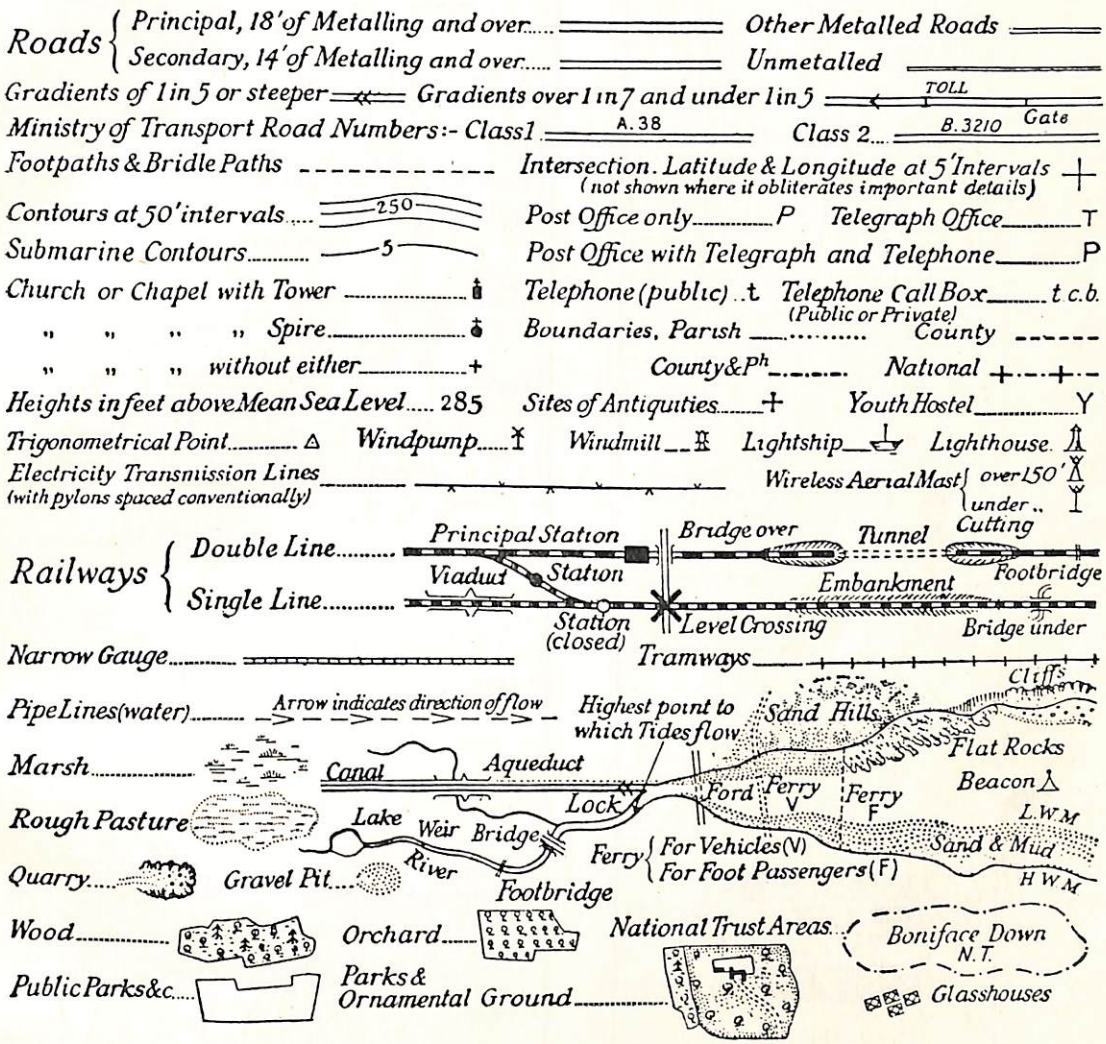


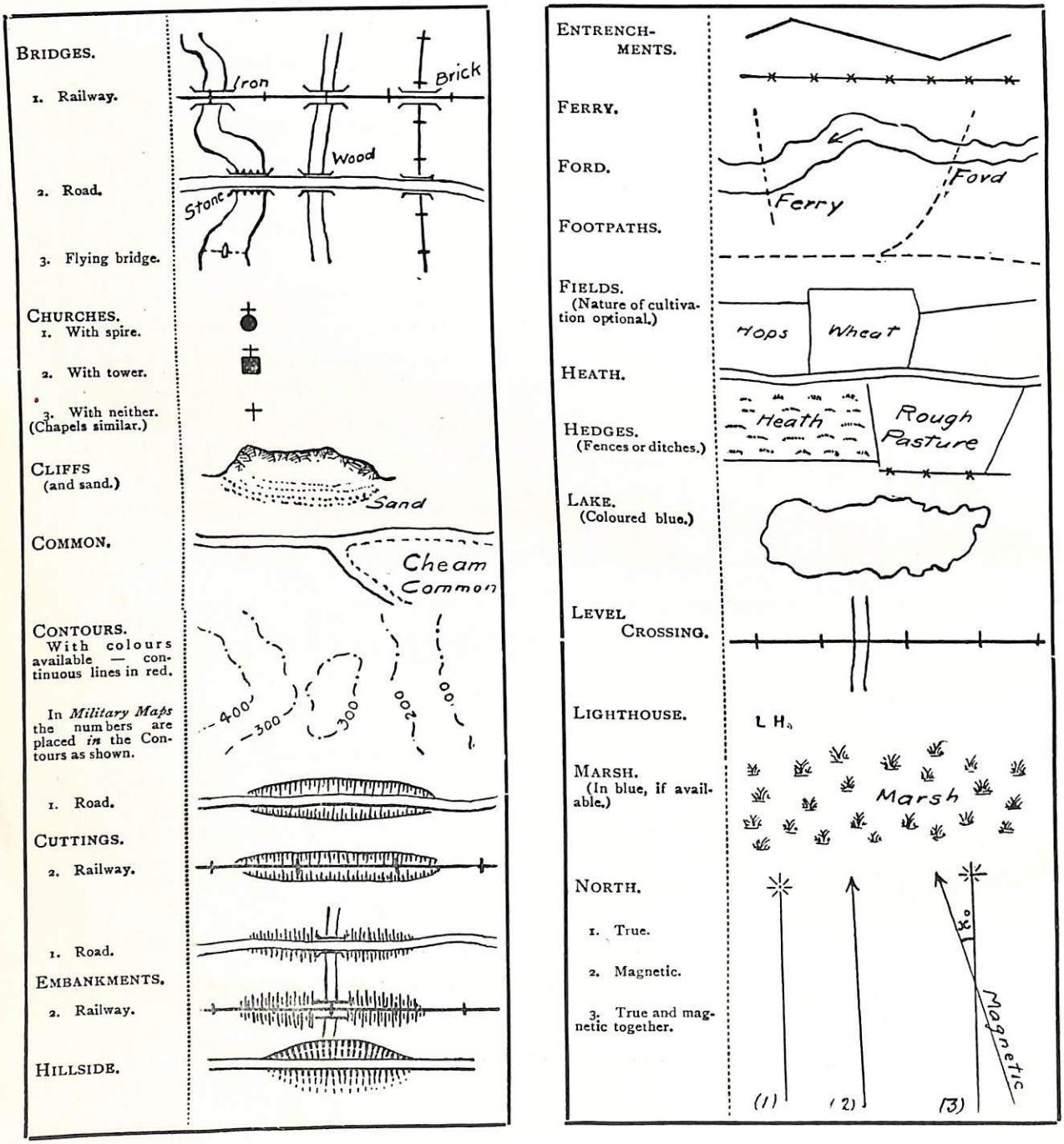
Fig. 3. Conventional Signs

(*Based upon the Ordnance Survey with the sanction of the Controller of H.M. Stationery Office.*)

A portion of an Ordnance Survey Map appears on page 82.

CONVENTIONAL SIGNS FOR MILITARY SKETCHES

(In Alphabetical Order)



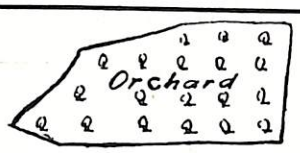
Only the words shown to the right of the dotted lines appear on the map.

Fig. 4

CONVENTIONAL SIGNS FOR MILITARY SKETCHES

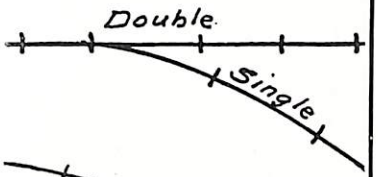
(In Alphabetical Order.)

ORCHARD.

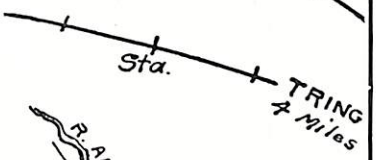


PRECIPICE } See
QUARRY } Cliff.

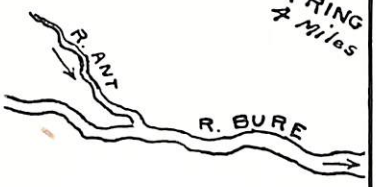
RAILWAYS.
Double rails and single rails. See also under Bridges, Cuttings, Embankments, Level Crossings, Tunnels.



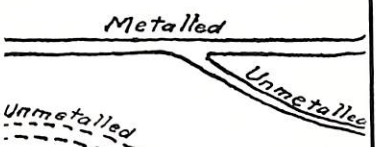
RLY. STATION.
Names and distance of next station at each margin.



RIVERS.
In blue if available. The width may be written across river.



ROADS.
1. Enclosed by hedge, fence, ditch, or wall, etc.



2. Unenclosed. If colour available metalled roads are coloured brown and the words omitted.

3. Enclosed on one side.

Note.—At each margin, name and distance of next place.

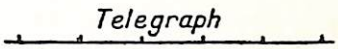
SIGN POST. S.P

SPOT HEIGHT. • 13.5

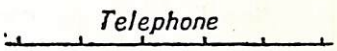
TELEGRAPH OFFICE. T

POST OFFICE P.

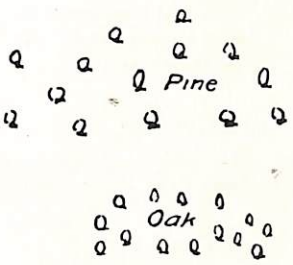
TELEGRAPH LINE.



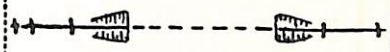
TELEPHONE LINE.



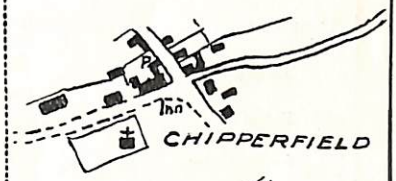
TREES.
(Their description to be added in writing.)



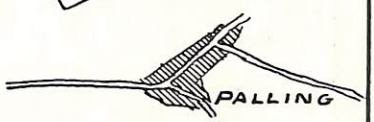
TUNNEL.
(Showing two short cuttings.)



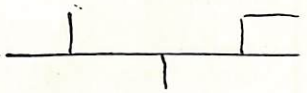
VILLAGES.
(Names in block letters.)
1. Large scale (4" = 1 mile.)



2. Small scale. (Under 4" = 1 mile.)



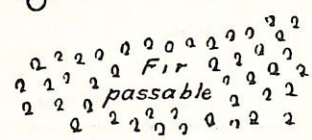
WALLS.



WELL.
(In blue, if available.)

WINDMILL.

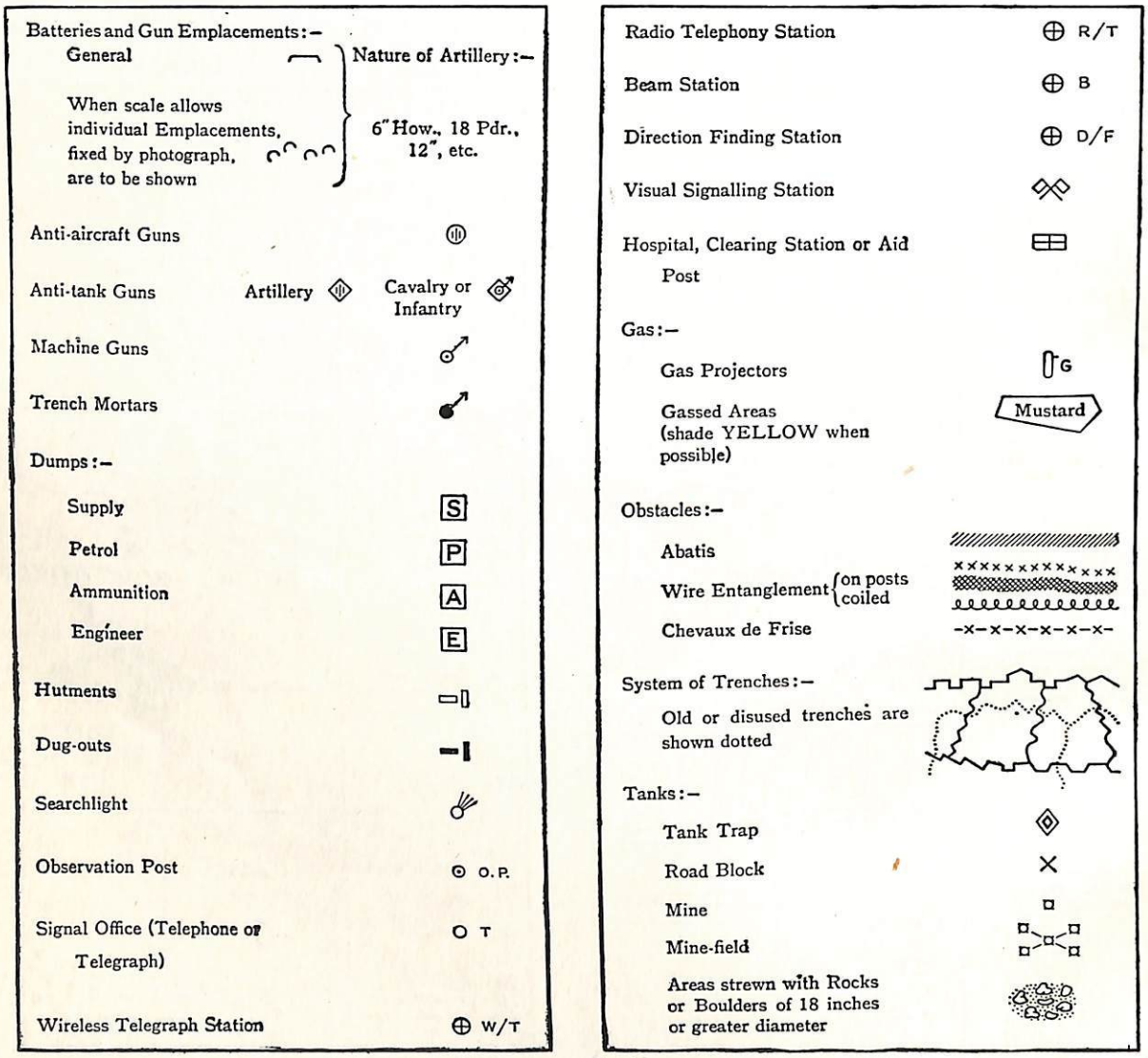
WOODS.
(In green, if available) or in *green* diagonals as shown below.
It should be noted in writing whether they are passable for troops of all arms or not, their nature (fir, oak, etc.), and the degree of cover afforded.



Only the words shown to the right of the dotted lines appear on the map.

Fig. 5

MILITARY CONVENTIONAL SIGNS TO BE USED ON MAPS, SKETCHES OR ANNOTATED PHOTOGRAPHS



Signs will be shown in RED for BRITISH (and ALLIES) and in BLUE for ENEMY

*An occupied emplacement is shown on Artillery maps by sign ● (1 Gun), unoccupied O, overprinted in another colour.

Fig. 6

MAP READING MADE EASY

PART I

RELIEF OF THE SURFACE

It has been pointed out in the Introduction that the various methods by which the **Relief of the Surface** of the land, viz. its hills, valleys, ridges, slopes, and plains, are shown on maps should be thoroughly understood. The methods chiefly employed for this purpose are:

1. Contours.
2. Spot Heights.
3. Hachures.
4. Layers.
5. All or some of the above in combination.

CONTOURS

Definition of a Contour. "The representation of an imaginary line running along the surface of the ground at the same height above mean sea level throughout its length."

On a map, a series of Contours are drawn, giving heights successively rising by an equal amount.

As shown on a map, they are plans of these imaginary lines, just as the map of an island is a plan of the water edge, thus giving the shape of the island.

Contours may perhaps be most easily explained by referring to the sketches on the next page:—

Fig. 7 is a view of an island as seen by an approaching vessel. Now let us suppose the sea rose say 100 feet to form a new coast line and that this line was permanently marked in white so that it could be seen from above in an aeroplane when the sea receded.

Then suppose the sea rose another 100 feet and another water edge was similarly marked out on the land and then again, giving levels of 100 feet, 200 feet, and 300 feet.

If the sea then sank to its original level the island will appear with the white lines as shown, and if seen from above they would appear as in Fig. 8, which would be a plan (or map) of the island showing Contours.

These Contours are numbered as shown, giving the height of each Contour above sea level and give an accurate idea of the height of any point on the map. For instance, the elevation of point A is between 100 feet and 200 feet: B is between 200 feet and 300 feet (on a steeper slope): and point C is exactly 300 feet above sea level.

Mean sea level is usually the starting-point from which all indications of height, on maps are taken, and is known as the **datum line**, so that when looking at different maps of the same area although the intervals between the Contour lines may vary considerably, according to the purpose for which the map is to be used, the actual heights they indicate always bear the same relation to the datum line.

The difference in height or level between the Contour lines varies on different maps, and it is obvious that the smaller the difference in height between them, the more accurately they will reproduce the nature of the surface. Thus if it were possible for them to be drawn at intervals of one

foot they would bring out every little inequality of the ground. To attempt to give so much detail, however, is impossible for two reasons—

1. Because the Contour lines would be so close together that no other information on the map could be read.
2. Because the cost of preparing a map in such detail would be prohibitive.

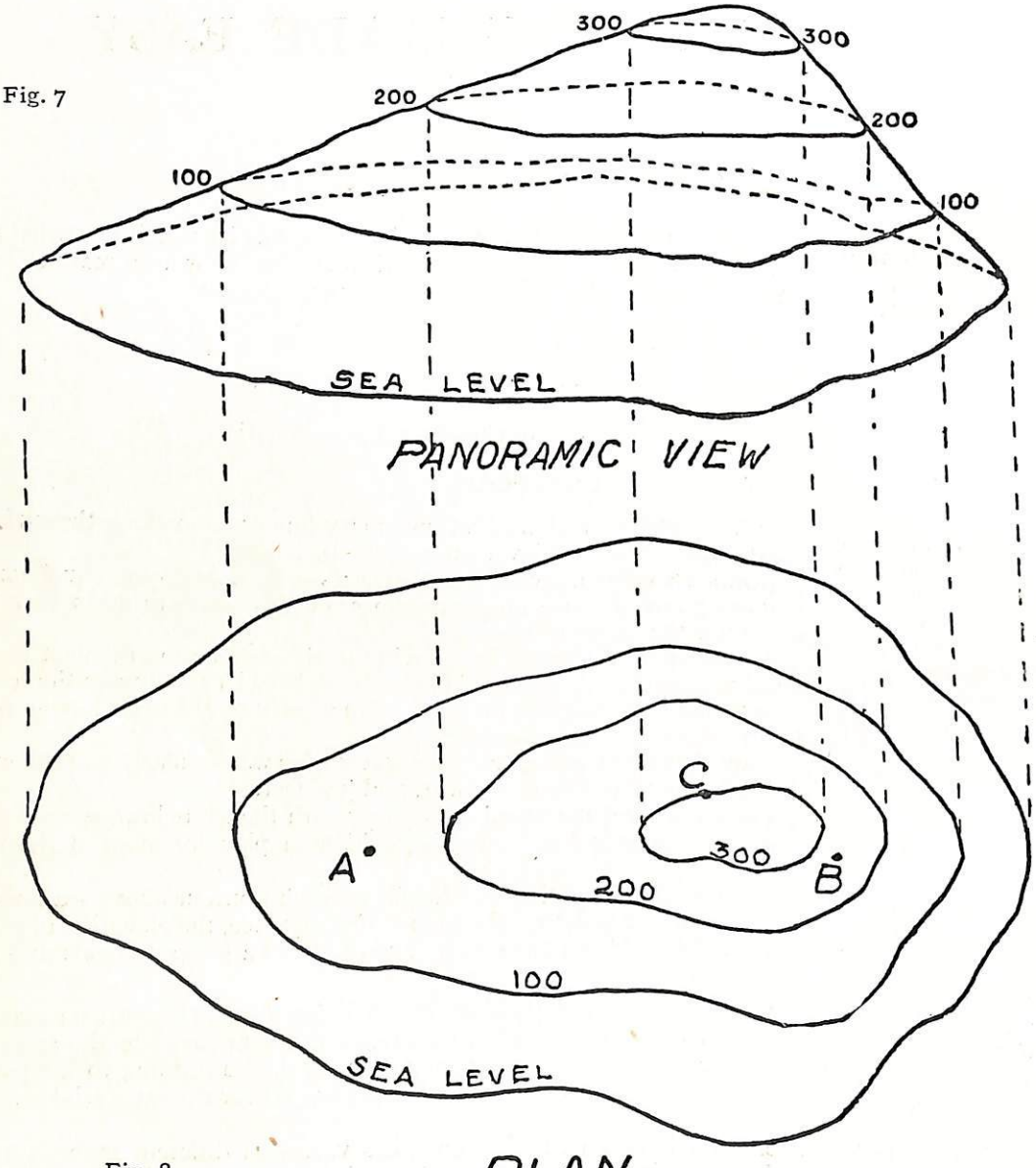


Fig. 7

Fig. 8

It is therefore necessary to draw the Contour lines at such a difference of level as will best bring out the characteristics of the surface of any particular piece of country, and this method is adopted in the maps published by our Ordnance Survey. Thus in the one-inch maps of hilly country like the Lake District, we find the difference in level between the Contours 100 feet and more, whilst in flat country, like the Eastern Counties, we find the difference in level between them only 25 feet.

Another factor which affects the amount of difference in level between the Contour lines is the relation between the size of the map and the size of the country which it represents. The nearer the size of the map corresponds with the size of the country it represents the larger the number of Contour lines which can be inserted without obscuring other detail.

SLOPES

Having learnt what Contour lines are, let us now consider what may be learnt by the study of the Contour lines on any particular map. The first thing is to ascertain what is the difference in level between them. Let us assume the Contour lines are inserted every 100 feet, which means that in moving from where one Contour line is marked on the map to the next, we have either to climb or descend a height of 100 feet. This is known as the Vertical Interval or V.I. between two adjacent Contours. It follows that in places where the Contours are drawn close together the distance to be travelled forward is small compared with the height to be climbed, and therefore a steep slope is indicated, but where the Contour lines are far apart the distance to be travelled forward is long compared with the height to be climbed, and therefore a gentle slope is indicated.

Besides being steep or gentle, slopes may be:

1. **Uniform,** or the same slope throughout, either steep or gentle, shown on the map by the Contours being equidistant. See Fig. 9. Slope AB and BC.
2. **Concave.** Beginning at the bottom with a gentle slope and ending with a steeper one, shown on the map by the lower Contours being drawn further apart than the higher Contours. See Fig. 10. Slope AB.
3. **Convex.** Beginning with a steep slope and ending with a gentler one, shown on the map by the lower Contours being closer together than the higher Contours. See Fig. 10. Slope BC.

Figs. 9 and 10 represent pieces of ground illustrating the three varieties of slopes mentioned above, and are drawn so that the slopes are shown not only as they would appear to the eye but also as the contoured map of the same area in perspective. Thus in each illustration the line AB^1 C on the map represents the path a person would follow when passing over the surface of the ground from A to C. And the Contour lines passing through D^1, E^1 and F^1 on the map represent the corresponding Contour lines passing through D, E and F on the surface of the ground.

Let us now examine the Contours on the maps representing each of the slopes. In Fig. 8, illustrating uniform slopes, we find that in the gentle slope AB, the distance travelled along the surface of the ground whilst climbing 100 feet from A to D is greater than the distance travelled along the surface of the steep slope BC, whilst climbing the same height from C to D. Consequently we find the Contour lines on the map between A and B^1 further apart than those between B^1 and C. Further, we find that the distance travelled along the surface for each 100 feet climbed throughout each of the slopes AB and BC is uniform, consequently the distances between the Contour lines on the map at D^1, E^1 and F^1 are also equal.

Fig. 10 illustrates Concave and Convex Slopes, and if the detailed explanation of Fig. 9 has been thoroughly grasped it will be clear that when the Contour lines on a map are placed wider apart at the bottom of a slope than at the top, as along the line A B^1, a Concave Slope resembling A B is indicated, and when the Contour lines are placed closer together at the bottom than at the top, as along the line B^1 C, then a Convex Slope is indicated resembling B C.

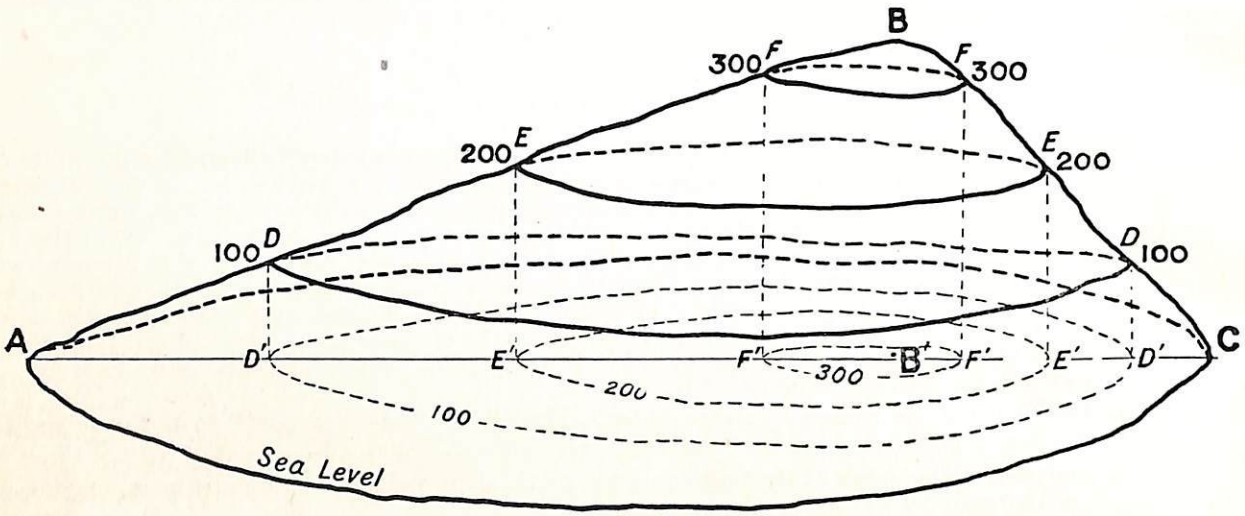


Fig. 9. Uniform Slopes—Gentle and Steep

From a study of these and the following illustrations and by studying the Contours on a map on the actual ground, the student will in time be able to construct a mental picture of the surface of any piece of ground afforded by the Contours shown on the map, and when this knowledge has been acquired one of the principal difficulties in Map Reading has been overcome.

The importance of this knowledge cannot be exaggerated, as without it, a good map is robbed of more than half its value.

If you want to get from one place to another, a knowledge of the distance between the two places and their direction one from another will not be of much assistance unless you can correctly judge the character of the surface which has to be crossed. A road which may be quite practicable for a pedestrian or a cyclist may be quite impracticable for a horse-driven vehicle, and very often the old adage " the longest way round is the shortest way home " will be found strictly true.

It may well be asked, if there are only three kinds of slopes, viz. Concave, Convex, and Uniform, how are we to treat ground, the surface of which is concave in one part and convex in another, and perhaps uniform in another.

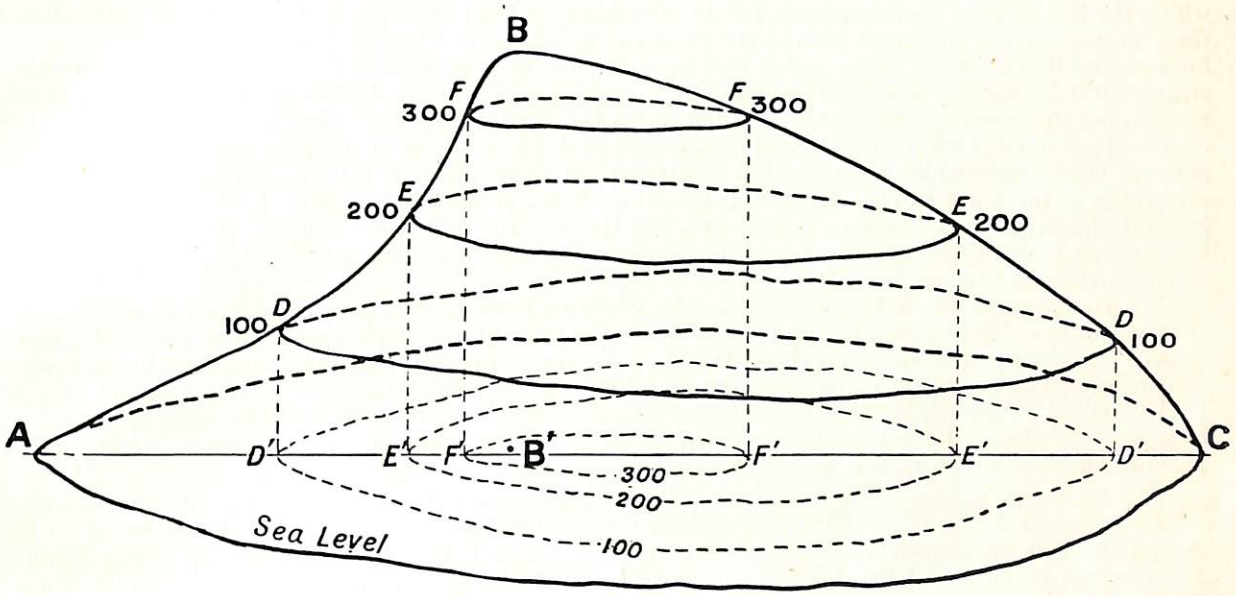


Fig. 10 Concave and Convex Slopes

The reply to this is that the surface of all ground of this kind must be, as a whole, either Concave or Convex, and in order to find out to which of the two it belongs it is only necessary to determine what is called its *general* characteristic.

In the case of a winding road between two places on the map, it will be found that certain parts of the road lead in totally different and sometimes opposite directions, but, by drawing a straight line from one end of the road to the other, its general direction can be correctly ascertained.

So, with the surface of any particular piece of ground, if we could see all its ups and downs in the same way as we can see the windings of a road on the map, we should be able to judge whether its general character was Concave or Convex, and consequently whether one part of the surface was visible from another.

The way to get such a view is by making what is called a section of the ground, showing what would be seen from one side, if a cut were made vertically into the Earth with a large knife and all the ground between you and the cut were removed in exactly the same way as if a piece were cut off an apple or loaf of bread. The part thus exposed is called a Section.

HOW TO MAKE A SECTION

In order to make a Section between any two points on a map, place the edge of a piece of paper along the line joining the two points; a piece of squared paper from a note-book will be suitable, or lines may be ruled on the paper parallel with its edge at uniform intervals. (See Fig. 11.)

Write against each horizontal line the figures corresponding with all the Contour lines through which the line of your Section passes, placing the figure of the lowest Contour against the bottom line, then draw a vertical line from each of the points at which the line of your Section crosses the Contour lines to the line on your paper which corresponds with that particular Contour. Then join up the ends of all these vertical lines and you will have a Section which shows the relative height of the various portions of the ground between the two points on the map; then if a straight line be drawn on the Section joining the two points at each end, it will enable you to see at once what is the general character of the surface which your Section illustrates. This line is called the line of sight, and if there is nothing to interrupt it, then the two points at each end of the Section are mutually visible, and the general character of the surface is Concave. If the line of sight is interrupted or broken by some intervening feature, then the two points are not visible from one another and the general character of the surface is Convex.

For the purpose of making a Section, the distance between the horizontal lines is immaterial, provided it is uniform; and, within certain limits, the more the vertical scale is exaggerated the more clearly the character of the slopes included in the Section is brought out. If the vertical heights were drawn in exact proportion to the horizontal distance, the elevation of the Section would be so small that it would be useless for the object for which it is intended. But the existence of this necessary exaggeration should be constantly borne in mind, otherwise, when looking at slopes on the actual ground, the eye will be misled and the amount of slope will be underestimated.

Fig. 10 shows how such a section as has been described should be constructed; the line of sight A^1 B^1 passes below the top of the intervening feature D^1, therefore the point B is not visible from A and the general character of the ground between A and B is convex, if the intervening feature D^1 were not so high and the line of sight A^1 B^1 passed above it then the general character of the surface would be concave and the two points would be mutually visible.

Dead Ground. By means of a Section it is also possible to measure the extent of dead ground which exists in any portion of the surface when viewed from any particular point. When the line of sight between two points is interrupted by an intervening feature another line of sight must be drawn passing just above the top of such intervening feature, and the Section must be extended to include the point where this new line meets the surface of the ground. Then if a perpendicular line be dropped from this point to the base line of the Section, and its position be marked on the map, the distance from the edge of the intervening feature to this point will represent the extent in depth of the ground which is hidden from an observer at the point from which the line of sight is drawn, such ground is called dead ground. See Fig. 12.

But in addition to knowing how far this dead ground extends in depth, we also require to know how far it extends on each side of the line of sight. In order to ascertain this, all that is necessary is to draw two additional lines or rays from the point occupied by the observer, one to each side of the highest Contour of the intervening feature; then if these rays are extended so as to meet a line drawn at right angles through the point to which the dead ground extends, the space enclosed by these three lines will represent the whole of the area hidden from the observer.

Fig. 11 also illustrates the foregoing. The line A^1 D^1 C^1 on Section shows where the line of sight from A^1 passing over the intervening feature D^1 meets the surface of the ground at C^1. If a perpendicular line is drawn from C^1 to the bottom of the Section where it rests on the map at the point C then the extent of dead ground beyond the intervening feature D can be measured as far as it extends in depth, i.e. away from an observer at A. The extent in width, i.e. to the right and left of an observer at A, of the dead ground is shown by drawing lines from A through each side of the 300 feet Contour line at D to E and E^1.

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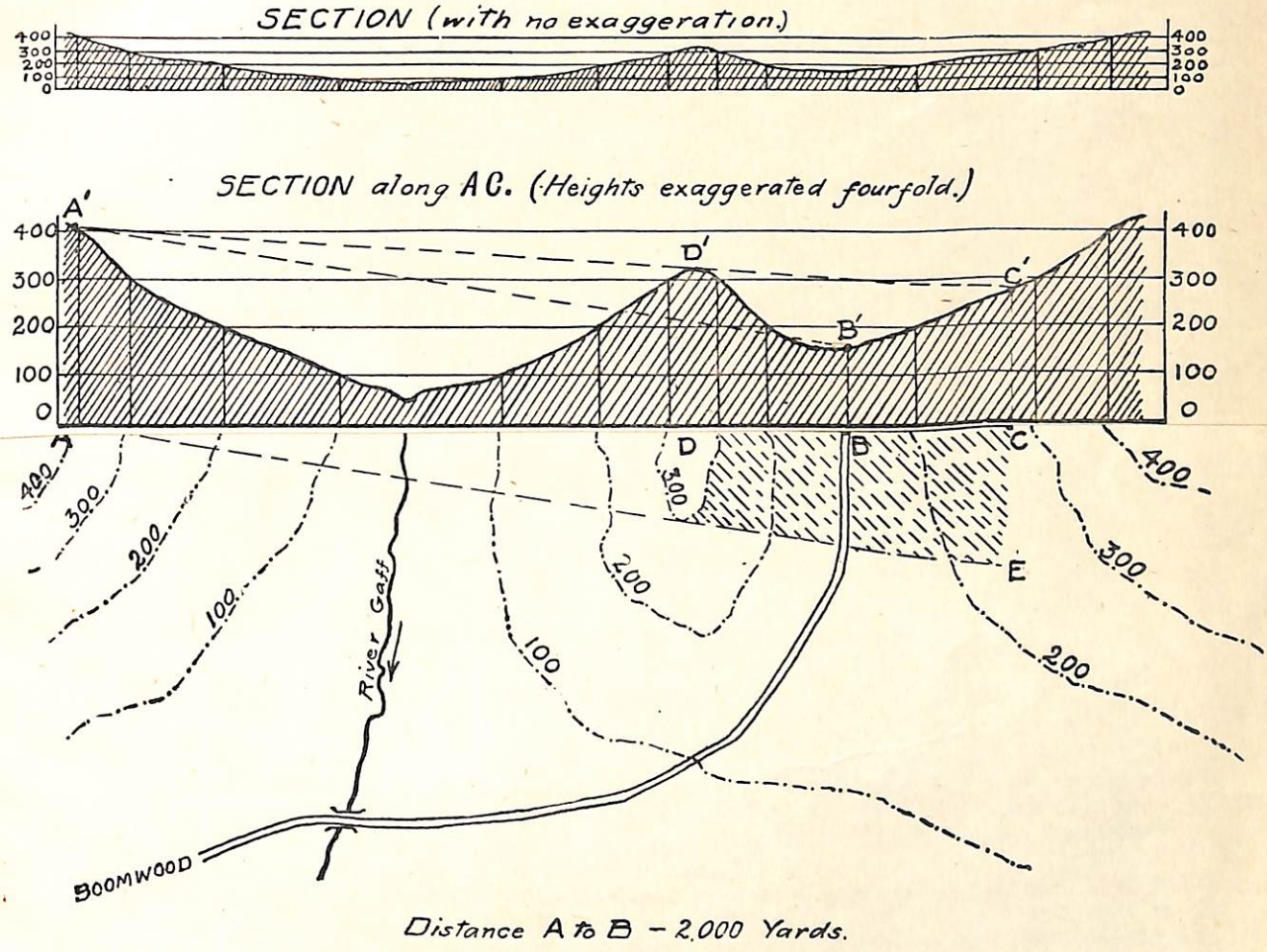

Fig. 11

NOTE.—The construction of a section for determining the mutual visibility of points is only advisable for instructional purposes, for practical work the methods explained on page 16*b* should be employed.

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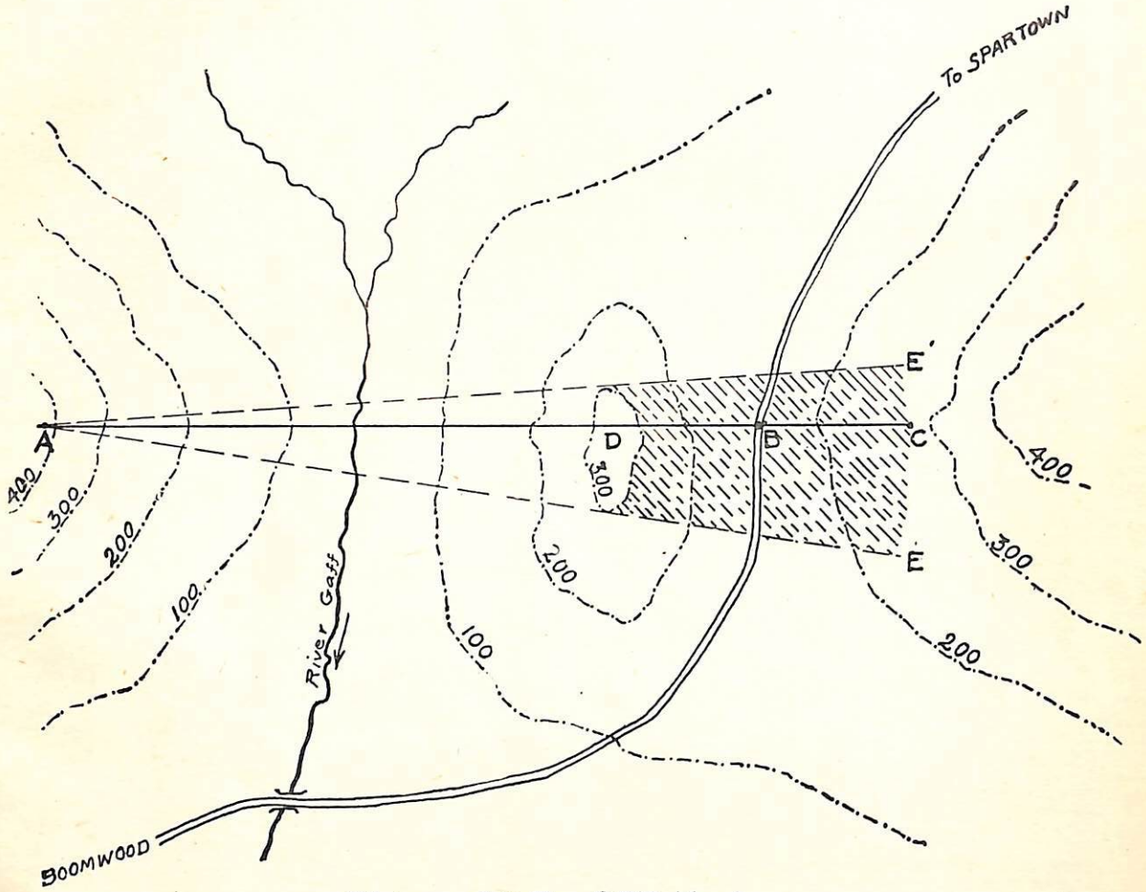

Fig. 11

NOTE.—The construction of a section for determining the mutual visibility of points is only advisable for instructional purposes, for practical work the methods explained on page 16*b* should be employed.

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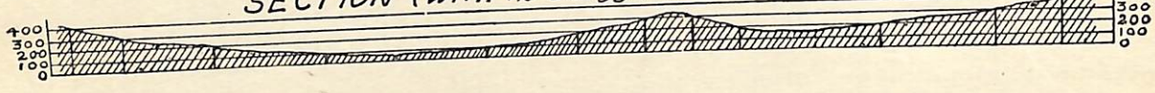
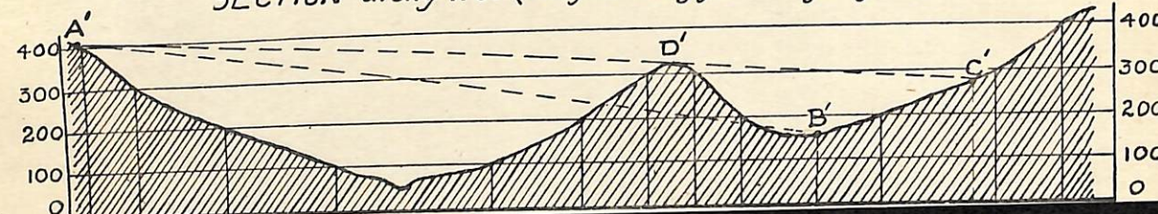
SECTION (with no exaggeration.)



SECTION along AC. (Heights exaggerated fourfold.)



It will be seen, however, that the 400 feet Contour line extends on each side of the observer's position at A, so that, if he moved to one side or the other, the extent of dead ground would vary; so, in order to ascertain the extent of ground which would be hidden from any observer standing at the same height, the rays must be drawn from each side of the Contour on which the observer is placed, and if this be done it will be obvious that the extent of dead ground would be considerably reduced in width.

If, instead of an observer, a searchlight were fixed at the same point, it would be possible to measure, in the same way, how much of the surrounding country would be illuminated and how much would be hidden.

Fig. 12 also illustrates Concave and Convex slopes and "dead ground," and shows the Contour lines as would be seen on the map.

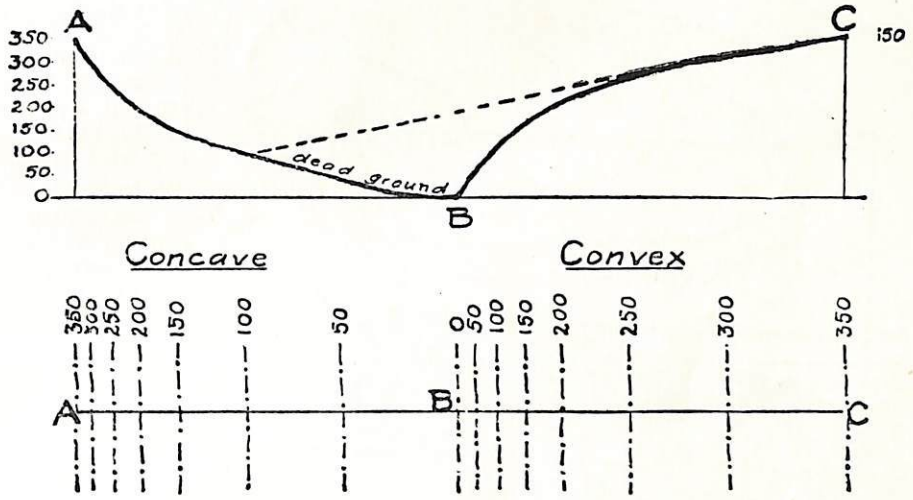


Fig. 12. Characteristics of Concave and Convex Slopes

VALLEYS AND SPURS. Having learnt how to recognize by means of the Contours the general characteristics of any portion of the surface, the next important matter is to be able to readily distinguish the difference between Contour lines representing Valleys or Re-entrants and Spurs or Salients, features which on the map closely resemble one another.

On the side of every mountain or range of mountains, and of every hill or line of hills, there are projections and depressions formed by the denudation or washing away of the softer rocks or soil in the course of centuries. The projections are known as Spurs or Salients, and the depressions as Valleys or Re-entrants.

Both these features bear a striking resemblance to one another when looked at on the map, and the general shape of the Contours by which they are represented may be said to somewhat resemble hairpins, the sides of which have been more or less widely opened.

In the case of a Valley or Re-entrant the closed end of the hairpin lies in the direction of the high ground, and the heights of the Contour lines decrease towards the open end. In the case of Spurs

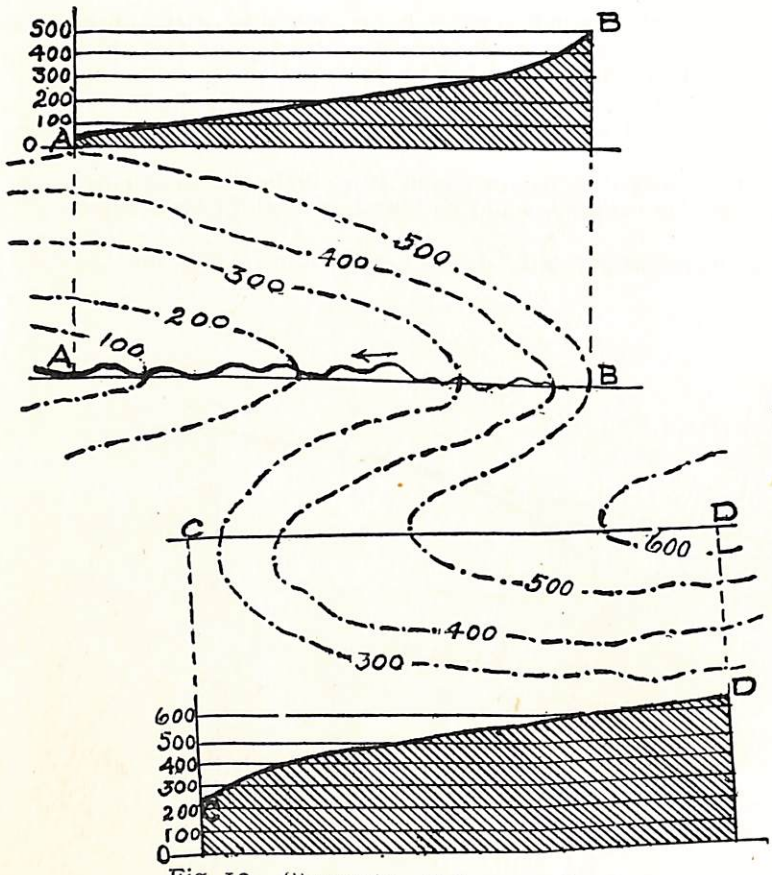


Fig. 13. Illustrating Valley and Spur

or Salients the closed end of the hairpin lies in the direction of the low ground and the heights of the Contours increase towards the open end.

Where a river or stream is shown on the map in connection with this arrangement of Contours the presence of a Valley is at once indicated and no time need be wasted in studying the Contours.

An examination of the accompanying illustration of Valleys and Spurs, Fig. 13, will make the foregoing abundantly clear and will also tell us something further, viz. :

1. That the Contour lines representing a Valley or Re-entrant are further apart at the bottom than at the top, and therefore its sides are *Concave.*
2. That the Contour lines representing a Spur or Salient are closer together at the bottom than at the top and therefore its sides are *Convex.*

It will be seen from an examination of the illustration that Valleys and Re-entrants are generally found to alternate with Spurs or Salients.

CHANGE OF SLOPE. Considerable difficulty is often experienced in recognizing on a Contoured map what is called a change of slope. For example, the point where the surface of ground forming a hill or ridge, or even a slight prominence begins to descend or the surface forming a valley or depression begins to ascend. The point to remember is that whatever distance the Contours are apart the same Contour lines have to be crossed when descending as in ascending, consequently the top of a hill or the bottom of a valley may always be recognized by the presence of two adjacent Contours marked with the same height.

Fig. 14 illustrates two very simple examples of change of slope.

If we look along the road from X–Y in accompanying diagram we see that it crosses two Contour lines at A^1 and A^2, both marked with the same height, it does the same at B^1 and B^2. By making a section along the line A–B, we see clearly that at each of these points there is a change of slope, so that anyone walking along the road would have to cross the same Contour twice, once when climbing the hill at A^1 and again at A^2 when descending the hill on the other side ; again the Contour would be crossed at B^1 at the bottom of the hill, and again at B^2 when climbing the next hill. At A^1 and A^2 and B^1 and B^2 the road crosses what appears on the map to be two precisely similar features (known as Ring Contours), yet in one case, A^1 and A^2, the road rises and then falls, and in the other case, B^1 and B^2, the road falls and then rises.

If you examine these two pairs of Contours more closely, you will see that at A^1 and A^2, the figures denoting the height of the Contours are placed inside the ring, whilst at B^1 and B^2, the figures are placed outside the ring, and it is only by the position of these figures that we can tell from the map

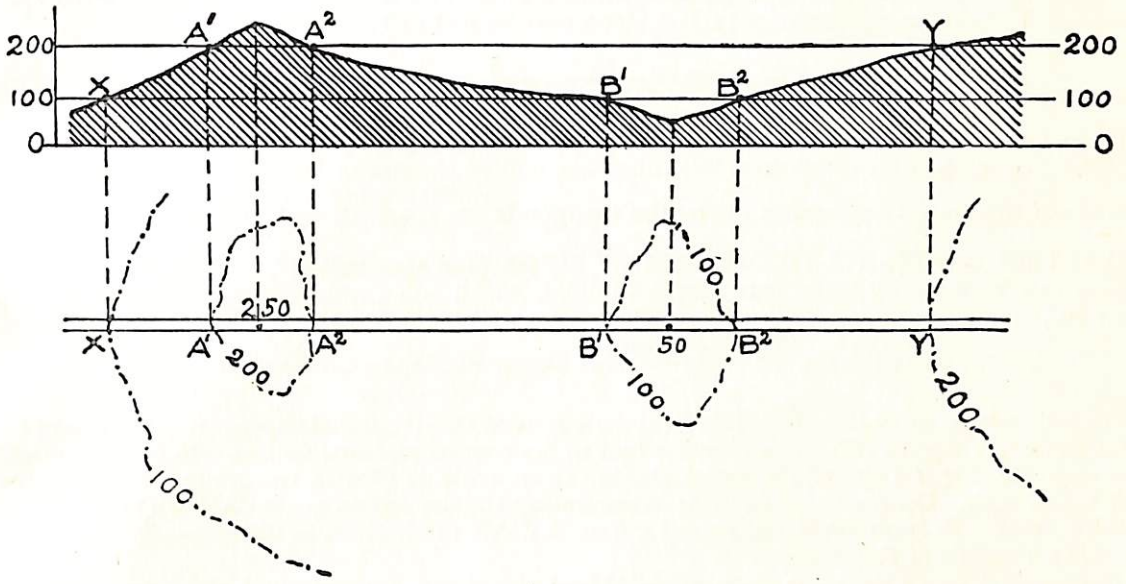


Fig. 14. Illustrating Change of Slope

whether a closed or Ring Contour denotes an elevation or depression, unless, as in our illustration, figures giving the exact height are added. From this we learn why it is so important to remember that, when drawing in the Contours on a map, the heights of the Contours should always be placed on the side of the line on which the ground rises.

It may here be noted that, in this country, Ring Contours indicating depressions of any considerable depth in the ground are unusual, as such depressions are generally filled with water.

MEASUREMENT OF SLOPES

It is not sufficient to be able to distinguish between different kinds of slopes—whether they are steep or gentle, concave, convex, or uniform; but we require to be able to measure slopes up to 15° to 20° with a certain amount of accuracy. This can be done from Contours.

Slopes over 20° have to be climbed practically on the hands and knees so need not be considered for all practical purposes, but it is necessary to be able to measure gentler slopes in order to know if they are ascendable (or suitable) for various purposes—such as for motor-car, cavalry, artillery, animals with wheeled traffic, infantry in close order, and railways, etc., the normal limits for which are of course known. Moreover, slopes have to be measured when *making* a contoured map or sketch.

How Measured. A Slope may be measured in two ways.

1. *By Degrees*, i.e. the number of degrees in the angle it makes with the horizontal plain, e.g. a Slope of 10°.
2. *By a Gradient*, expressed as a fraction, with the rise as numerator and the horizontal distance (in the same unit of measurement) as denominator.

$$\text{Thus the Gradient} = \frac{\text{Rise}}{\text{Horizontal distance}}$$

For instance, if a Slope rose 20 feet in 100 yards (300 feet) the Gradient would be $\frac{20}{300}=\frac{1}{15}$ which conveys to you that the rise is 1 in 15.

Gradients are generally expressed with the numerator as 1, so that Slopes may be compared.

To take another example: if a Slope rises 25 feet in 170 yards, then

$$\text{Gradient}=\frac{25'}{(170\times 3)'}=\frac{5}{102}=\frac{1}{20\cdot 4}$$

To find the Gradient of a Slope between two points on a map you ascertain from the Contours the difference in their altitudes, and this difference will be the rise in *feet*. You also ascertain (from the scale of the map) the distance in *feet* the two points are apart, then the Gradient $=\frac{\text{rise}}{\text{distance}}$.

CONVERTING GRADIENTS TO DEGREES OF SLOPE (and vice versa).

This can be done by using this simple formula, which is accurate enough for all Slopes up to 15° or 20°.

$$\text{Gradient}=\frac{\text{Degree of Slope}}{60} \textit{ or } \text{Degree of Slope}=\text{Gradient}\times 60$$

We will endeavour to show how this formula is arrived at. By actual experiment it has been found that a slope of 1 degree (1°) has a rise of 1 foot in (as near as matters) 60 feet. Referring to folding plate opposite, Fig. (*a*) shows a slope of planks, at an angle of 1° with the ground, leading up to a bank 1 foot high. Diagram (*b*) shows AC representing the slope at an angle CAB of 1° with the horizontal ground. BC represents the rise of 1 foot and AB the horizontal distance—60 feet. This is called the Triangle of Reference.

Diagram (*c*) shows the same slope AC of 1° and also slopes drawn from A at angles of 2°, 3°, 4°, 5°, 6°, 7°, 8°, 9°, 10°, 11°, 12°, 13°, 14°, and 15° with the horizontal AB.

These angles are all accurately drawn, and it will be seen that—up to 15°—the divisions along BD are all practically equal. Thus for every additional degree there is an additional rise of 1 foot in 60 feet, and we can see that

A slope of 1° has a rise of 1 foot in 60 feet. Gradient $=\frac{1}{60}$

" " 2° " " 2 feet in 60 feet. Gradient $=\frac{2}{60}$

" " 3° " " 3 feet in 60 feet. Gradient $=\frac{3}{60}$

" " 4° " " 4 feet in 60 feet. Gradient $=\frac{4}{60}$

" " 5° " " 5 feet in 60 feet. Gradient $=\frac{5}{60}$

and so on up to a slope of

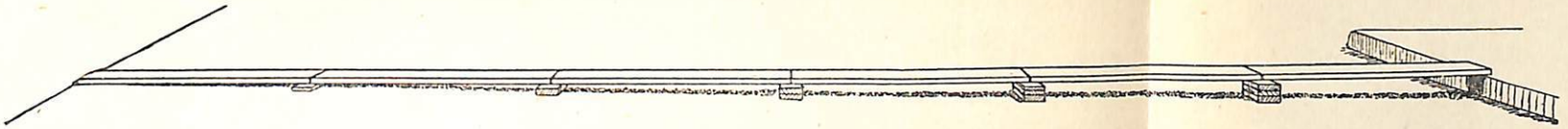
15° with a rise of 15 feet in 60 feet. Gradient $=\frac{15}{60}$

This proves that up to 15°, Gradient $=\frac{\text{Degree of Slope}}{60}$ (or Degree of Slope $=$ Gradient $\times$ 60)

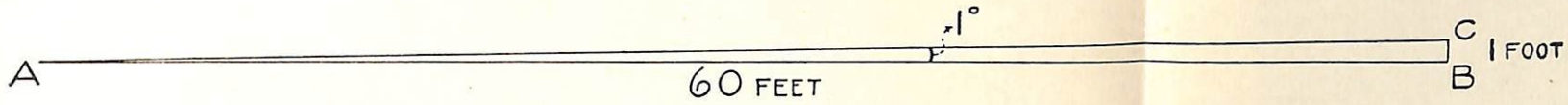
Examples.

1. A slope of 7° has a Gradient $=\frac{7}{60}=\frac{1}{8\cdot 57}$

2. If a slope has a Gradient of $\frac{1}{6}$, then its Degree of Slope $=\frac{1}{6}\times 60=10°$

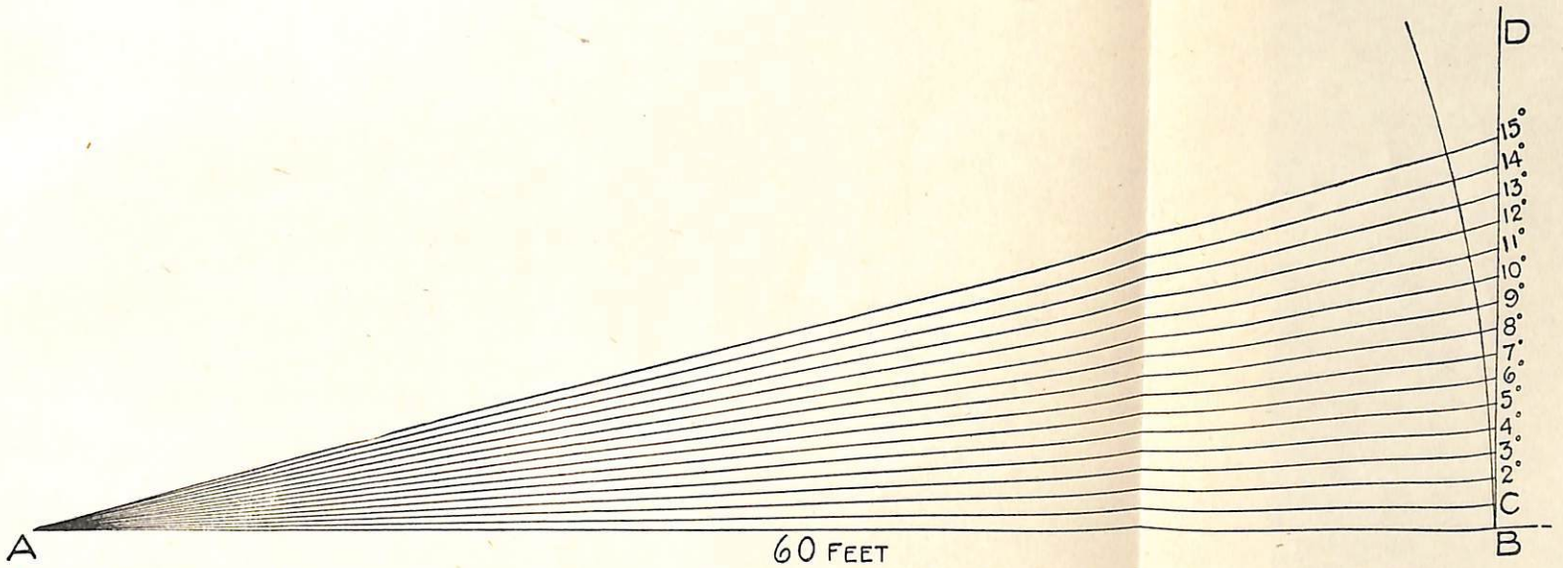


(*a*) SHOWING A SLOPE OF PLANKS AT 1° WITH THE HORIZONTAL.



(*b*) TRIANGLE OF REFERENCE, showing that a slope (AC) of 1° rises 1 foot (BC) in a horizontal distance (AB) of 60 feet.

$$\text{Gradient} = \frac{\text{Rise}}{\text{Distance}} = \frac{1}{60}$$



(*c*) SHOWING SLOPES OF 1° (AC), 2°, 3°, 4°, 5°, 6°, 7°, 8°, 9°, 10°, 11°, 12°, 13°, 14°, and 15° with the horizontal AB.

Fig. 14A

Notes.—1. In proving the formula, on opposite page, that $\text{Gradient} = \frac{\text{Degree of Slope,}}{60}$ we have assumed that the divisions on BD made by the lines representing the slopes are all equal. This is not absolutely mathematically correct. A part of the circumference of a circle is shown drawn with A as centre and AB as radius. The slopes have been accurately drawn, and every two adjacent lines form an angle of 1°, so that the small arcs opposite these angles are degrees and of course are all equal in length. It will be seen that the farther the arc gets from the vertical line BD the greater will be the rise for each additional degree before reaching BD. Up to 15° or 20°, however, there is very little difference, so that the formula is quite near enough for these slopes. Beyond these angles the formula is of no use as the increase of rise per degree becomes more and more apparent.

2. It will be noticed that the lengths of the slopes (up to 15°) are very little longer than the horizontal distance AB, and for the purposes of Map Reading they are considered the same length.

3. The actual horizontal distance travelled at 1° for a rise of 1 foot is 57.3 feet, but the round figure of 60 feet as given above is quite accurate enough for the purpose.

[*To face page* 16

MUTUAL VISIBILITY OF POINTS DETERMINED BY A COMPARISON OF GRADIENTS.

Once the method of ascertaining the gradient and angle of any slope is understood, the difficulty experienced in deciding whether any two points on a map are mutually visible can be solved without the necessity of making a section of the ground. All that is necessary is to compare the gradients of the two slopes formed (1) by the line of sight between the two points, and (2) by the line of sight between the higher of the two points and the intervening feature.

In Fig. 15A we have a map of the same ground that was used to illustrate the making of a section (Fig. 11, facing page 12).

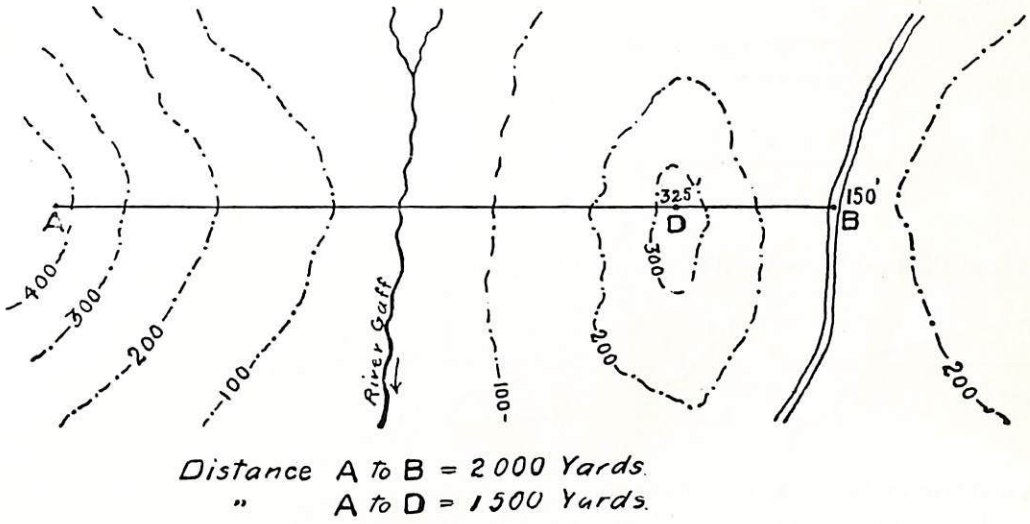


Fig. 15A

A and B are the two points and D is the intervening feature.

The distance from A to B is 2000 yds. and the difference in height between A and B is 250 ft.

Therefore the gradient of the slope AB is

$$\frac{\text{Rise}}{\text{Horizontal Distance}} \quad \frac{250 \text{ ft.}}{2000 \times 3} = \frac{1}{24}$$

The distance from A to D is 1500 yds. and the difference in height between A and D is 75 ft.

Therefore the gradient of the slope AD is

$$\frac{\text{Rise}}{\text{Horizontal Distance}} \quad \frac{75 \text{ ft.}}{1500 \times 3} = \frac{1}{60}$$

It is therefore clear that the slope AB is steeper than the slope AD, and consequently the intervening feature D must rise above the line of sight AB so that the two points are not mutually visible.

Fig. 15B illustrates the foregoing diagrammatically.

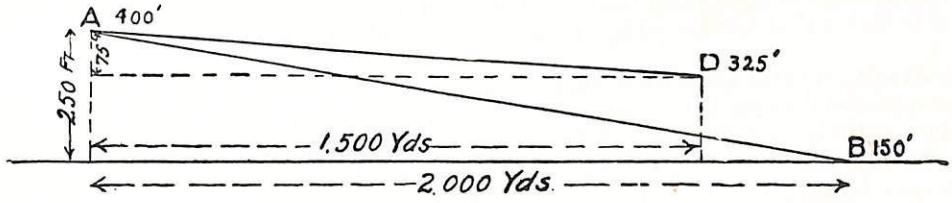


Fig. 15B

Another very similar method is to compare the gradients of the two slopes formed by lines of sight from the intervening feature to each of the two points the mutual visibility of which is to be determined. Thus if the gradient of the slope between A and D is less that that between D and B, then the general character of the ground between A and B is convex, and A and B are not mutually visible. If the gradient of the slope AB is greater than DB, then the general character of the ground between A and B is concave, and AB are mutually visible.

If the gradient of the two slopes is the same, then the general character of the ground is uniform, and the mutual visibility of the two points will depend upon the existence of such surface features as woods or buildings.

Fig 15c illustrates this method applied to the same ground as shown in Fig 15a.

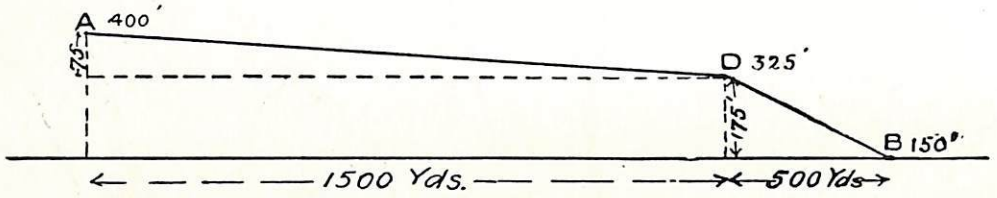


Fig. 15c

This method can be reduced to the following formula, which is easily remembered :—

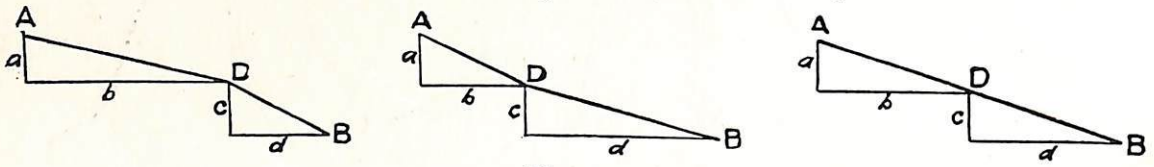


Fig. 15d

A and B represent the two points on the map and D is the intervening feature :—

(a) = difference in height between A and D. (b) = distance of A from D.
(c) = ,, ,, D and B. (d) = ,, ,, D ,, B.

If $\frac{a}{b}$ is less than $\frac{c}{d}$ general character of ground is convex.

If $\frac{a}{b}$ is greater than $\frac{c}{d}$ general character of ground is concave.

If $\frac{a}{b}$ is the same as $\frac{c}{d}$ general character of ground is uniform.

In cases where there are numerous intervening features likely to interfere with the line of sight between any two points on the map, use photo reading, the method described in the official *Manual of Map Reading, Photo Reading and Field Sketching*, Section 36, Fourth Method.

This consists of dividing the line of sight into equal divisions corresponding with the number of vertical intervals between the two points.

Each division indicates where the contour line would fall if the slope between the two points were uniform; therefore, if the actual contour line crosses the line of sight above its corresponding division, it shows that the line of sight must pass above it. But if it crosses below the division, it shows that the ground is higher than the line of sight; and consequently the two points would not be mutually visible.

The great advantage of these methods for practical work is that their accuracy does not depend upon constructional drawing in connection with which a slight error due to the use of a blunt pencil may produce entirely wrong results. When using small scale maps (such as the half or one inch Ordnance Survey) it is important to bear in mind that the distance between the points under consideration may be such that their mutual visibility under normal weather conditions is impossible even with the aid of glasses, irrespective of the nature of the intervening ground.

MAKING A SCALE OF SLOPES for a Contoured Map.

A Scale of Slopes enables you to tell from the *length* of any line between two *adjacent* Contours what is the degree of slope of that ground.

The Vertical Interval (V.I.), as explained, is the difference in level between any two *adjacent* Contours and is always stated on the map.

The Horizontal Equivalent (H.E.) is the name given to the horizontal distance between two adjacent Contours.

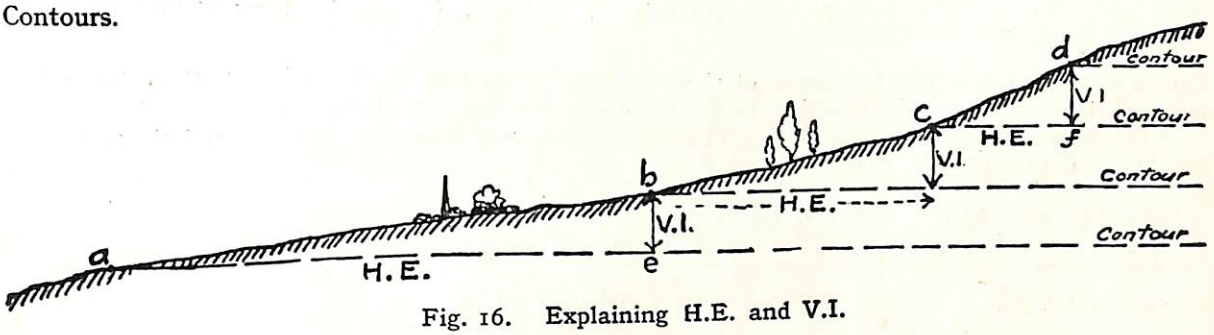


Fig. 16. Explaining H.E. and V.I.

In the above figure is shown a section of a hill, showing the heights of 4 dotted Contour lines at a, b, c, and d. The V.I. does not vary, but the H.E. varies in length according to the degree of the slope. It will be seen that a e, which is the Horizontal Equivalent of the slope a b, is much longer than c f, the H.E. of the slope c d.

In each case the slope between two adjacent Contours has a Gradient $=\frac{\text{V.I. (in feet)}}{\text{H.E.(in feet)}}$ i.e. $\frac{\text{Rise}}{\text{Distanee}}$

Now we have shown on the previous page that a Gradient $=\frac{\text{Degree of Slope}}{60}$

$$\therefore \frac{\text{V.I.}'}{\text{H.E.}'}=\frac{\text{Degree of Slope}}{60} \text{ or Degree of Slope}=\frac{\text{V.I.}'\times 60}{\text{H.E.}'} \text{ or H.E.}'=\frac{\text{V.I.}'\times 60}{\text{Degree of Slope}}$$

From this formula, as we know the V.I. (which is stated on the map) we can work out the H.E. for slopes of 1°, 2°, 3°, 4°, etc. up to 15°—the H.E. being the distance shown on the map representing the slope between two adjacent Contours. Let us take an example.

Suppose the V.I. = 20 feet. Scale of map 6 inches = 1 mile.

	Distance represented on Map.
For a slope of 1° H.E. $=\frac{20\times 60}{1}$ feet = 1200 feet = 400 yards.	1·36 inches
„ „ 2° H.E. $=\frac{20\times 60}{2}$ feet = 600 feet = 200 yards.	·68 inches
„ „ 3° H.E. $=\frac{20\times 60}{3}$ feet = 400 feet = 133 yards.	·45 inches
„ „ 4° H.E. $=\frac{20\times 60}{4}$ feet = 300 feet = 100 yards.	·34 inches
„ „ 5° H.E. $=\frac{20\times 60}{5}$ feet = 240 feet = 80 yards.	·27 inches
„ „ 6° H.E. $=\frac{20\times 60}{6}$ feet = 200 feet = 66 yards.	·22 inches
„ „ 7° H.E. $=\frac{20\times 60}{7}$ feet = 171 feet = 57 yards.	·19 inches

and so on up to 15°.

Now work out what distances these H.E.'s 400 yards, 200 yards, 133 yards, etc., would be represented by on the map.

Take 400 yards. 1 mile is represented by 6″ on map

or 1760 yards ,, ,, 6″

∴ 1 yard ,, ,, $\frac{6''}{1760}$

∴ 400 yards ,, ,, $\left(\frac{6}{1760}\times 400\right)''=1\cdot36$ ins.

Thus a slope (between two Contours) of 1° would be 1·36 ins. long on the map. If the other H.E.'s are worked out they will be found to be as stated above against the distances.

Now draw a straight line and mark off the measurements of inches in succession and the respective number of degree on top, thus :

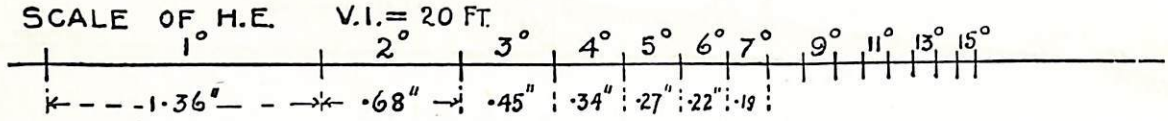


Fig. 17. A Scale of Slopes

By transferring the scale to a slip of paper the degree of slope of any part of the map can be obtained from the distance between adjacent Contour lines ; or any length on the map of a slope between two adjacent Contour lines can be taken with the dividers, and the nearest corresponding division on the scale will give the degree of slope.

Note.—1. The lengths of the divisions are only put in for explanation.

2. Decimals of inches can be accurately obtained from the Decimal Scale of Inches. (See page 81.)

3. The Scale can be made for ½ degrees.

It is useful to put the Gradient corresponding to the degree of slope underneath the divisions, and thus get a scale of Gradients.

A Scale of Slopes is more particularly useful in making a sketch of ground with Contours. The slopes are measured on the actual ground with a clinometer, which gives the degree of a slope, and from the scale the H.E. can be obtained.

SPOT HEIGHTS

Spot Heights. As already explained at the beginning of this chapter, the nature of the surface of the ground can also be indicated by what are called *Spot Heights*. These are figures indicating the height of the ground at certain isolated points, including Trig. Points, and usually along roads. Spot Heights are often found combined with Contours.

Fig. 18 shows a map with Spot Heights only, and Fig. 19 shows the same map with the Contours added at every 100 feet.

The following exercise will be found useful :—If one or more Spot Heights are given on blank contoured map, and the V.I. between the Contour lines is known, the height of each Contour line can be inserted, care being taken that the height of each Contour line is an exact multiple of the V.I. In this exercise, the marking of the Contours should be started at the Contour nearest to the highest Spot Height.

On a Hachured or merely shaded map, Spot Heights give the only *exact* information as to level which the map contains.

They are also particularly useful for showing minor relief between Contours. They should only be shown where the exact point is actually recognisable on the ground.

Trigonometrical Points are permanent marks in metal or stone and indicate the corners of triangles which form an accurate skeleton or network to which the detail of the map is fitted.

Bench Marks are the heights of main points in a system of levels and are permanent recorders on buildings, culverts, posts, etc.

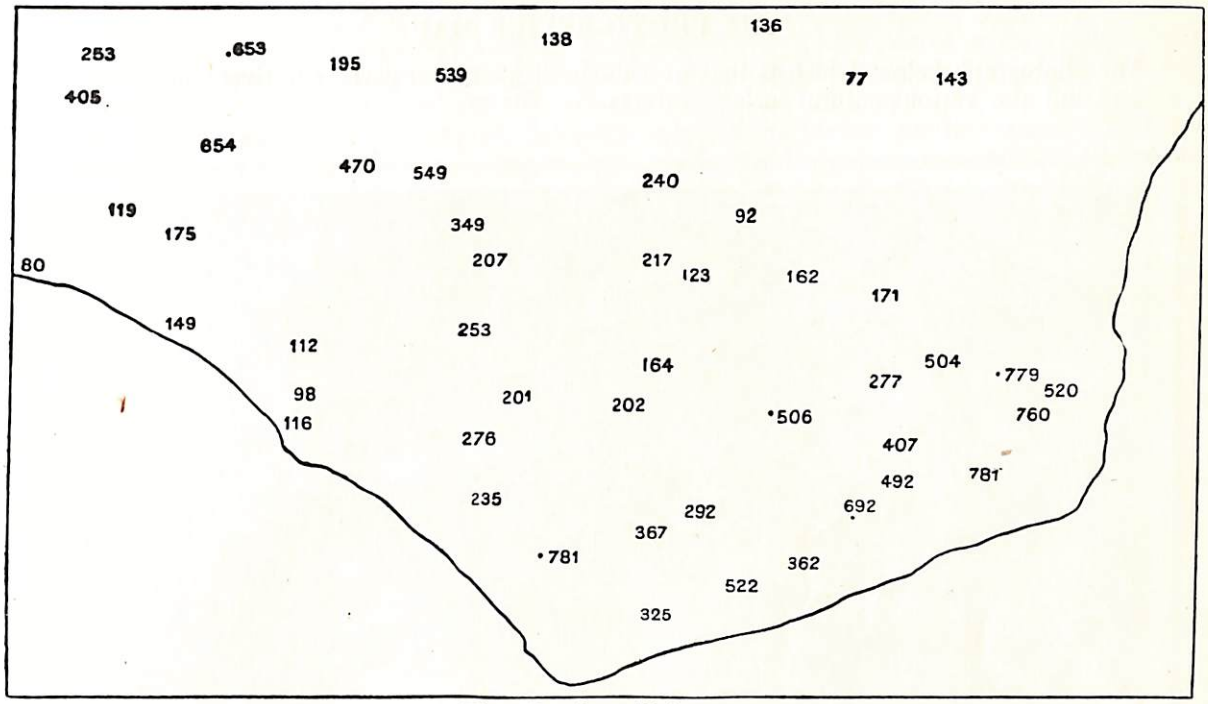


Fig. 18. Spot Heights

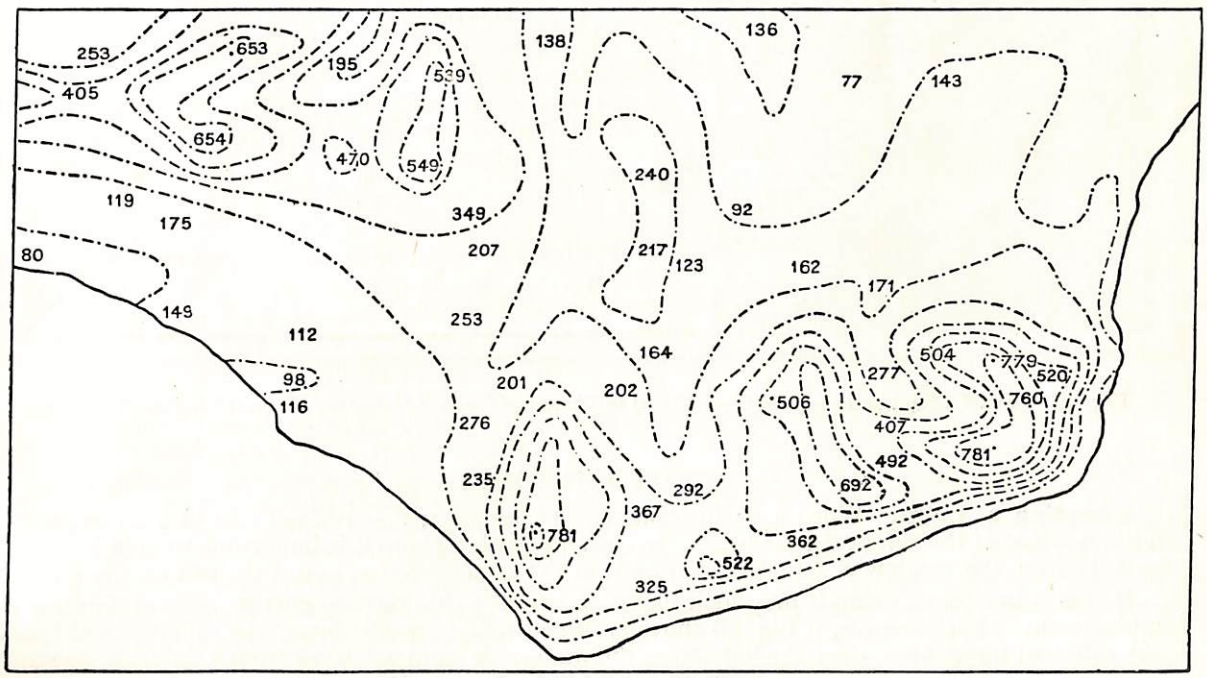


Fig. 19. Spot Heights with Contours

THE PHOTO-RELIEF MAP

The photograph below, which is that of a model in plaster-of-paris, effectively shows the relief of land and also various natural surface features.

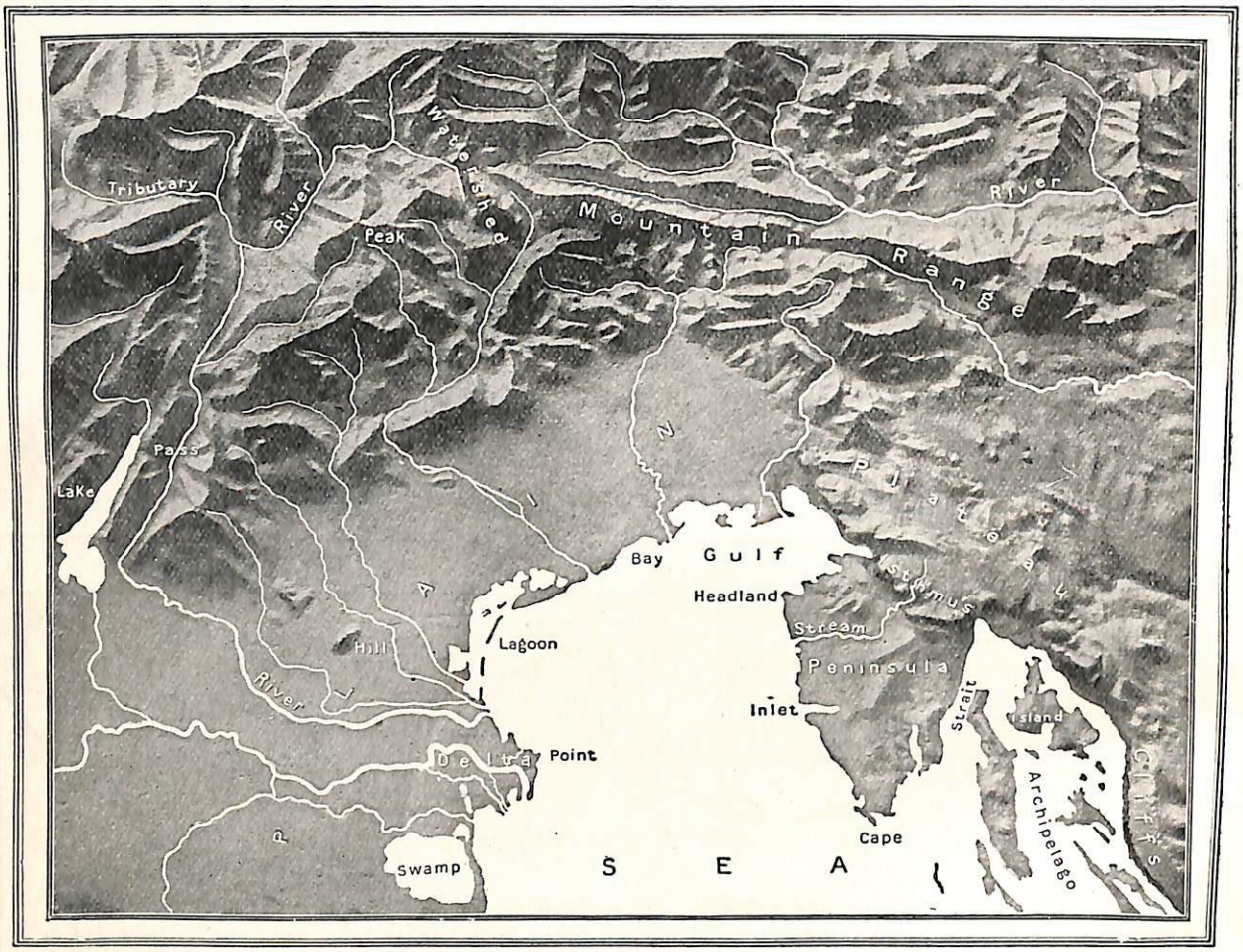


Fig. 20. Relief Map photographed from Model in Plaster of Paris, illustrating Natural Surface Features

PHOTO READING

Direction of Light. When a vertical photograph is taken, shadows are cast in a direction due to the position of the sun at the moment. In studying such a photo it is important to hold it so that the light from the window or lamp will fall on it in the same direction as did the sun on the ground.

If this is not done, mounds may look like excavations and a railway cutting be mistaken for an embankment. For example, if Fig. 20 above is turned round, upside down, the shadows will give a very different impression, since the light from the window or lamp will come from a different direction

from that when the photo was taken: ground in high relief appears as the reverse, i.e. as a depression, and vice versa. Such an error would be made in other directions; for example, a large isolated tree would probably appear in a photo as a dark spot with a dark shadow, and if you know the direction of light you will know at which end the tree will be.

Use with maps. A photograph usually shows only a small portion of the ground. The area photographed, both as regards extent and position, can be defined only by reference to a map containing the area. To facilitate this reference, all aerial photographs, whether taken by the old or new types of camera in use, bear on their face (1) an arrow indicating approximately True North, (2) a map reference, (3) the date and time of taking the photograph, and (4) the altitude and focal length of the lens of the camera.

The information given by showing the North point and adding a map reference helps the viewer to locate the area photographed on the map. The addition of the date and time gives him some clue as to the amount of light (and consequently, shadow) he may expect to see on the print. The altitude, and focal length of the lens of the camera, supply him with sufficient information to determine the horizontal scale of the photograph. Thus, all are of the greatest importance and should be studied carefully before an examination of the photograph begins.

There are two kinds of aerial photographs :—

Obliques, taken with the camera pointing earthwards at an angle of between 40° and 60°, and

Verticals, taken with the camera pointing vertically downwards.

Taken at any angle, shadows on flat ground normally appear longer than those on photos taken vertically; but the length of shadow will depend also upon the angle of the sun's rays. At noon they will be less pronounced than in the morning or the evening; hence the necessity of adding the time at which the photograph was taken on every print.

OBLIQUES

These show a sector of the ground bounded by lines from the camera opening out at an angle of about 50°. The country is shown in perspective, and buildings, etc. appear foreshortened. They are useful as showing the nature of the ground, and may be consulted to discover, for example, desirable routes in an operation. They are always used singly, as an aeroplane travels too fast to obtain a series of them to be used in conjunction with one another as with Verticals.

VERTICALS

Verticals show all details in plan, as in a map, except those under trees or camouflaged. Nearly all military photos are verticals, they being the most useful and most easily taken. They can be used :—

(1) **Singly.** Some hints on identifying objects are given (on following page). A single vertical shows no hills or valleys or heights, though it gives some clues to them.

(2) **In pairs with a stereoscope.** Verticals are generally made in strips, one photo showing an overlap of 50 per cent. of the preceding photo. For example, if two photos are taken from two points a mile apart in the air, then the overlap (about half of each photo) will show the same piece of country from two different points of view. This is a great help in identifying objects.

The two overlaps, looked at in a stereoscope, give a view of the country as a raised model, showing hills and valleys and other objects clearly in relief. It is important that the direction of light on the photos when using the stereoscope is in the correct position relative to the shadows on photos (see page 20).

(3) **In mosaic form.** Mosaics are made by piecing together all the photos taken in strips. Before piecing them together the overlap must be cut away, and the stereoscope is of no use after this has been done. Mosaics are rarely available on service.

IDENTIFICATION OF OBJECTS ON VERTICAL PHOTOS

The chief helps are from *shape, tone* and *shadow*. As objects appear in plan the Conventional Signs will be a help as to shape. As to tone, colour has not much effect, the tone depending chiefly on the reflection of light. The more light reflected towards the camera the whiter it appears on the photo. The time of day affects the amount of reflection and also the length of shadow.

At times, when the sun is prevented from shining directly on to the ground by the passage of a heavy cloud, shadows will be cast over big areas, and thus a photograph may carry bright reflections on one part, and dull reflections on another. This factor should always be borne in mind.

The following are hints gathered from the official manual on the appearance of various features.

Railways. Medium grey—due to broken surface of the permanent way. They have straighter lengths and more regular curves than roads. The rails cannot be seen on the average scale photos, but at a low altitude of 5,000 feet their shadows may be seen.

Roads. (1) Tarred : dark grey—they would appear black did they not reflect indirect light. Usually narrow light strips appear along each side due to accumulation of dust.

(2) Macadamized—light grey.

(3) Tracks and paths—light grey. The earth or grass, being well trodden down, reflects light. Tracks or paths are generally straight, and even wheel-tracks show two light lines.

Embankments and cuttings. Slopes facing the sun, white or light grey ; slopes in shadow—darker than the ground. Here it is important to know the direction of light (see page 20). These considerations apply also to cliffs and steep hills.

Bare Ground. Light shade, like unmade roads. Chalky soil shows white patches, clay soil a darker shade, and sandy soil a light shade.

Grassland. Light to medium grey, short grass showing light. Heath and patches of coarse grass give a mottled appearance.

Crops, when young. Light shade similar to grass, but showing darker as they get older, though ripe corn would show lighter. An interesting fact is that a field of mangolds might show white owing to their large smooth leaves reflecting light in all directions. Regular lines of crops such as potatoes and beans give a ruled appearance. Highly cultivated land would show a patchwork of various shades.

Hedges. Dark lines, with or without shadow.

Fences, ditches and walls do not show up on such a small scale except by their shadows when the sun is low.

Trees, bushes and scrub. Medium grey to black owing to the mixed reflections and shadow Woods give a patchy appearance. Isolated trees appear as a black dot with a lighter shadow, a pond, on the other hand, as a black spot without a shadow.

Water. Dark grey or black, unless the sun was high, and reflected light into the camera, when it would appear white. Rough water, sea or streams show some white patches. Canals show dark grey or black, tow-paths as white lines.

Buildings. White owing to their flat surfaces. They cast clear and black shadows. A hayrick might be mistaken for a cottage, but isolated buildings usually have a well-defined track leading to them showing light.

DATA ON A PHOTO

A type of camera known as the F.8 is generally used, and in the margin of each photo the following information is given :—

1. Map reference : e.g. 0.62.72
2. North Point

} To find position on Map.

3. Altitude
4. Type of camera and focal length

} To ascertain the Scale.

5. Date
6. Time (shown on clock) } To give position of the Sun and thus Direction of Light and Shadows.
7. Serial number of photo.
8. Unit taking photo.

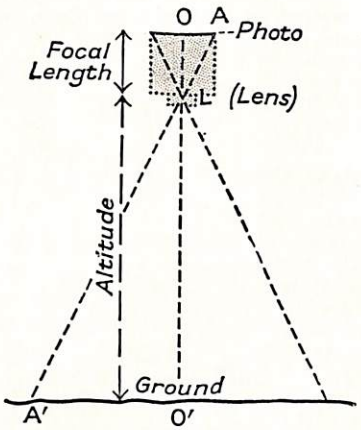


Fig. 21

THE SCALE OF VERTICALS

The scale of Verticals can be obtained thus:—

$$\text{Scale} = \frac{\text{Focal length of lens}}{\text{Altitude (in same unit of measurement)}}$$

(Fig. 21 shows how this is arrived at).

OA (half the photo) represents A'O' on ground.

Then, Scale $= \frac{OA}{A'O'}$ (expressed as a Representative Fraction).

But $\frac{OA}{A'O'} = \frac{OL}{LO'}$

Therefore, Scale $= \frac{OL}{LO'} = \frac{\text{Focal length}}{\text{Altitude}}$

Example: Focal length 10 inches. Altitude 12,000 feet.

Then, Scale $= \frac{10''}{(12{,}000 \times 12)''} = \frac{1}{14{,}400}$ (4.4 inches to one mile).

The average Scale is roughly three inches to the mile.

Note.—*In this book Scales are dealt with on pages* 67 *to* 81.

TYPES OF COMPASSES

Magnetic Compasses may be divided into two classes :—

1. WITHOUT a graduated dial fixed to the magnet.

(a) The ordinary Compass has a graduated card fixed to the bottom of the compass and is very inconvenient for taking bearings.

(b) **The Trough Compass** has a magnet poised in a narrow rectangular box, in the bottom of which at each end are engraved only five degree divisions on each side of Zero, which is in the centre. If the box is moved about until the needle points to Zero, then the central axis is pointing North and South. As the sides of the box are exactly parallel to the axis. a line can be drawn along either side, which will be the Magnetic North line. This is used for Plane Table drawing.

2. WITH a graduated dial fixed to the magnet (Card Compasses), e.g. Prismatic Compasses. In these the card revolves with the needle, the Zero being over the North-seeking point. Compasses of this class may be of the "dry" type, where the needle and dial revolve in the air, or of the "liquid" type where the needle and dial are immersed in a liquid composed of a mixture of alcohol (or glycerine) and distilled water. The dial is much steadier in the latter type and bearings can be taken more quickly.

The using of the Prismatic Compass is described in subsequent pages and various sketches of the dry type will be seen. Fig. 22 shows the latest service pattern (liquid type).

A Stout hinged Brass Case, external diameter 2 inches. Engine divided to 64 Compass Points.

B Glass Window upon which is etched a fine sight line.

C Prism Holder with focussing arrangement.

D Compass interior box containing transparent edge dial, divided to single degrees, mounted with sapphire centre floating in liquid upon an irridium point, also a trough containing radium compound and a patent bubble trap.

E Transparent Rotary Scale divided every 5 degrees and figured every 10 degrees (the noughts being omitted to give clearness of reading).

F Illuminated Index on rotary scale glass.

GG Notches for aligning compass upon Plane table or map.

H Clamp for rotary scale.

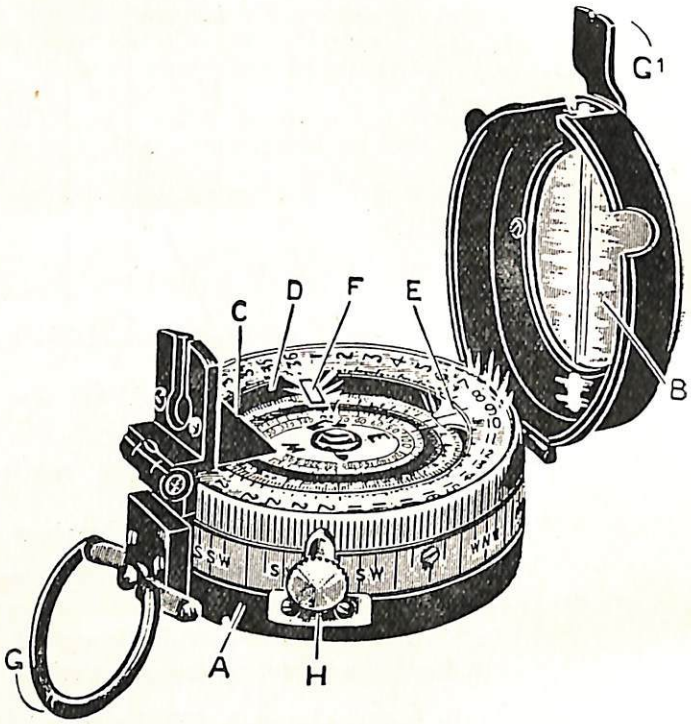


Fig. 22. The latest Service Pattern Liquid Prismatic Compass

DISTURBANCE OF THE COMPASS THROUGH IRON

The near presence of iron always affects a compass, and bearings should not be taken in close proximity thereto. The following are minimum safe distances :—

Heavy gun . .	60 yards	Barbed wire . .	10 yards
Field gun . .	40 ,,	Steel helmet . .	3 ,,
Telegraph wires .	40 ,,	Cap badge . .	½ ,,

Dumps, railroads, tractors, corrugated iron and such-like should be avoided. The Prismatic Compass cannot be employed (nor indeed any compass) when the user is wearing 'field marching order,' with his steel helmet, his respirator at the *alert*, and possibly carrying a revolver and wearing metal-framed spectacles. Owing to the attraction which the iron in these objects has for the compass needle, where it is used it is essential that the revolver and steel helmet should be placed at least 3 ft. away from the compass, e.g. at the foot of the user ; the respirator altered from the *alert* to the *slung* position and the spectacles removed. Iron ore, below the ground, is a common cause of error and is difficult to detect—except by the behaviour of the compass. Pipe lines below the ground may be a cause, but one has some idea where to expect them.

PART II

DIRECTION

SETTING THE MAP

In order to make proper use of a map you must be able to identify on the ground the various objects shown on the map and their position in relation to your own. To do this you must know how to lay out your map to correspond with the country which it represents, so that the North point on the map corresponds with the actual North, and that a line from the point on the map which represents your own position to any other point on the map is the real direction of the same point in the actual country. This is called *Setting the Map.*

Everyone is familiar with those large engravings representing cricket matches, or groups of celebrated soldiers, hanging up in clubs and hotels, with a small outline underneath forming a key to the engraving. In order to identify the figures in such groups it is necessary to refer to the small outline key on which the names are printed. But in order to use such a key easily both the engraving and the outline must be correctly placed in relation to one another. If you regard the engraving as the country and the small outline key as the map, you will understand what is meant by Setting the Map.

On page 61, Fig. 94 represents some actual country and shows a map of same which is "set."

It will be noticed that the direction on the map from the point c, which represents the spot on which you are standing, to any object, coincides with the actual direction in the country. Thus the lines on the map from c to the windmill, the station and to the church are respectively directly in line with these actual distant objects.

Objects of Setting a Map.

1. **For the purpose of studying it, i.e. comparing it with the actual country.**
   For this purpose it may be set approximately either holding it or laying it flat on the ground or a horizontal surface.
   When thus placed in correct position, any feature can at once be easily located, and contours may be compared with the hill features.
   The Scale may with advantage be considered on the actual ground.

2. **For the purpose of finding your position on the map.**
   The method will be explained.
   In this case the map must be *accurately* "set."

3. **The direction of a place marked on the map from the previously unknown position on which you stand, can then be ascertained.**

4. **For adding additional information to the Map, such as drawing a ray to some object not depicted on the map, judging its distance away and putting it in.**
   In this case also, it must be *accurately* set.

The methods of setting the Map are given on pages 60 to 66.

TRUE NORTH

True North from any spot is the direction of a line from that spot pointing to the earth's North Pole. Such a line is also known as a meridian—running from the South Pole through the spot to the North Pole. The direction of True North should be clearly displayed on all maps. It is usually given in a corner of the map by a conventional sign (see p. 4). It is sometimes given by meridians drawn across the map at regular intervals. Sometimes their extremities at the top and bottom of the map (see Fig. 98, page 64) are only given, and by joining them, the direction of True North can be found.

To draw a line on a map from any spot to True North, it will therefore have to be drawn through that spot parallel to the direction given.

METHODS OF FINDING TRUE NORTH

1. **By Compass.** Lay the Compass on the paper and mark the direction to which the needle points by joining the dots you make at each end. Then allow for the Compass Variation by using the Protractor. These are explained later.

2. **By the Pole Star.** The stars all revolve round the Celestial North Pole, and the *Pole Star* is very near this point and revolves round it in a very small circle and is always practically True North (within 2 degrees). This star can be found—

   (*a*) *From the Great Bear* (sometimes called the Plough), consisting of a group of seven stars, which move round the Pole Star in a large circle and always keep in the same relative positions to it and the same distance from it. Sometimes the group is seen above and sometimes below, or to either side of it.

   The Pole Star is found from the two front body stars called the pointers, which always point to the Pole Star. The diagrams on the opposite page show a dotted line from the pointers to the Pole Star. The arrows show the direction in which the group revolves round the Pole Star.

   The Great Bear does not sink below the horizon in England. Two diagrams are given to show the Great Bear in two different positions.

   The map-reader should accustom himself to finding the Pole Star quickly—when the Great Bear is in different positions. (The middle tail star is called *Zeta* and when it is vertically above or below the Pole Star, as happens to be the case in the diagrams, the Pole Star is then *exactly* True North.)

   (*b*) *Cassiopeia*, which is on the other side of the Pole Star to the Great Bear. This group consists of five stars which form two angles pointing away from the Pole Star. A line bisecting the more acute angle points to the Pole Star (Figs. 23 and 24).

3. **In the Southern Hemisphere** (i.e. south of the Equator) the Southern Cross is used:—

   Consider the Southern Cross as a kite; prolong the greater axis $4\frac{1}{2}$ times in the direction of the tail, and the point reached will be approximately the South Pole of the heavens. This can be done by marking the edge of a piece of paper with 12 lines equidistant apart, giving 11 divisions. If it is then held up so that the first and third divisions coincide with the head and tail stars respectively, the twelfth line on the paper will give the approximate *South* point.

   (When the long limb is *vertical*, it will be in the direction of True *South*.)

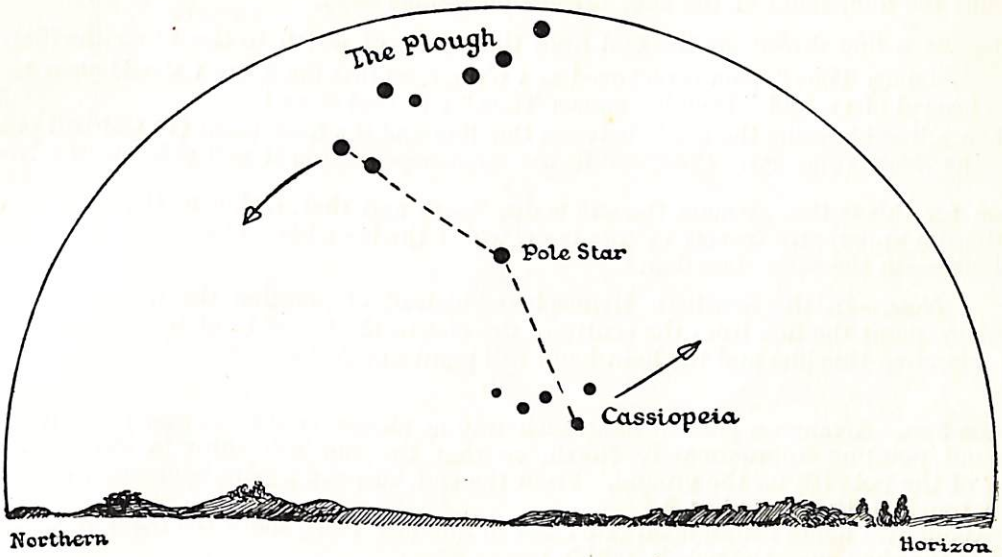


Fig. 23.

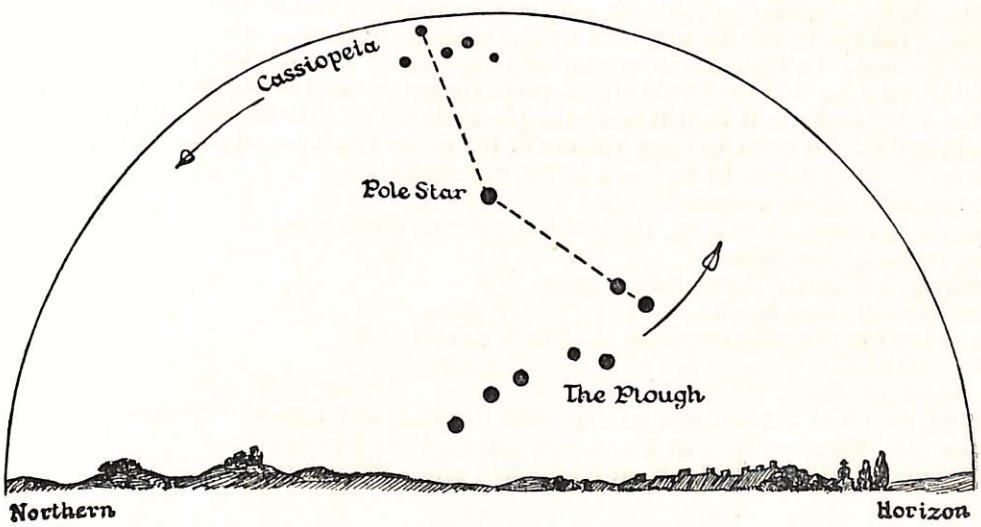


Fig. 24. How to find the Pole Star

4. **With a Watch** (approximate and useless in the tropics).

(*a*) Point the hour hand at the sun. *Ignore the minute hand.*

(*b*) Imagine a line drawn on the dial from the centre of watch to the 12 on the dial. (In "Summer Time" noon is reckoned as 1 o'clock, so that the figure 1 should then be used instead of 12, and "Double Summer Time," 2 instead of 12.)

(*c*) Then a line bisecting the angle between this line and the hour hand (12 CS) will point to the *South* (Fig. 25). Produced in the opposite direction it will point to the North.

The reason for this is that at noon the sun is due South and that, owing to the earth rotating on its axis, the sun apparently travels 15° per hour, whilst the hour hand of a watch moves 30° per hour—just double—in the same direction.

Note.—In the Southern Hemisphere, instead of pointing the hour hand to the sun, point the line from the centre of the dial to the figure 12 at the sun and the line bisecting this line and the hour hand will point due *North.*

5. **From the Sun.** Arrange a pole in some such way as shown in Fig. 26 and place it on the ground pointing approximately North, so that the sun will throw a shadow of the end of the pole (P) on the ground. From the end, suspend a plumb-line with the weight just touching the ground at A.

About two hours before noon (1 o'clock in Summer Time) mark the point B, where the end of the shadow of the pole is, with a peg.

Draw a circle with A as centre and AB as radius. The shadow will shorten, as the sun should be at its highest at noon. It will then lengthen again and should be carefully watched at about 1·45 p.m. until it touches the circumference of the circle again at C, which point should be at once marked with another peg.

Bisect BC at D and join AD.

Then AD will point to True North.

In the Southern Hemisphere it will point True South.

This is a good method, as it eliminates the question of the time in use at the place differing from local time. If the observer's position is not too near the poles this method is accurate.

On a Table. True North can be obtained by the same method on a table (in the open) on which paper has been pinned. In this case drop some sealing wax on a penny and press the unsharpened end of a pencil thereon, so that the pencil stands perfectly upright and in the centre of the coin. Then place it on the table and use it as if it were the plumb-line PA. The shadow of the pencil's point will give you B and C. In order to draw the arc of the circle, run a pencil point round the coin and find the centre. The penny can be replaced in the pencilled circle.

The following points are of interest.

The chancel of a church faces *East,* the porch usually on *North* side.

Tombstones usually face *East.*

Moss usually grows on the *North* side of trees.

Walled trees usually face *South.*

Branches of trees are usually longer on the South side.

The Sun (approximate).

On March 21st and September 21st, sun rises due East at 6 a.m. and sets due West at 6 p.m.

On June 21st, sun rises N.E. at 4 a.m. and sets N.W. at 8 p.m.

On December 21st, sun rises S.E. at 8 a.m. and sets S.W. at 4 p.m.

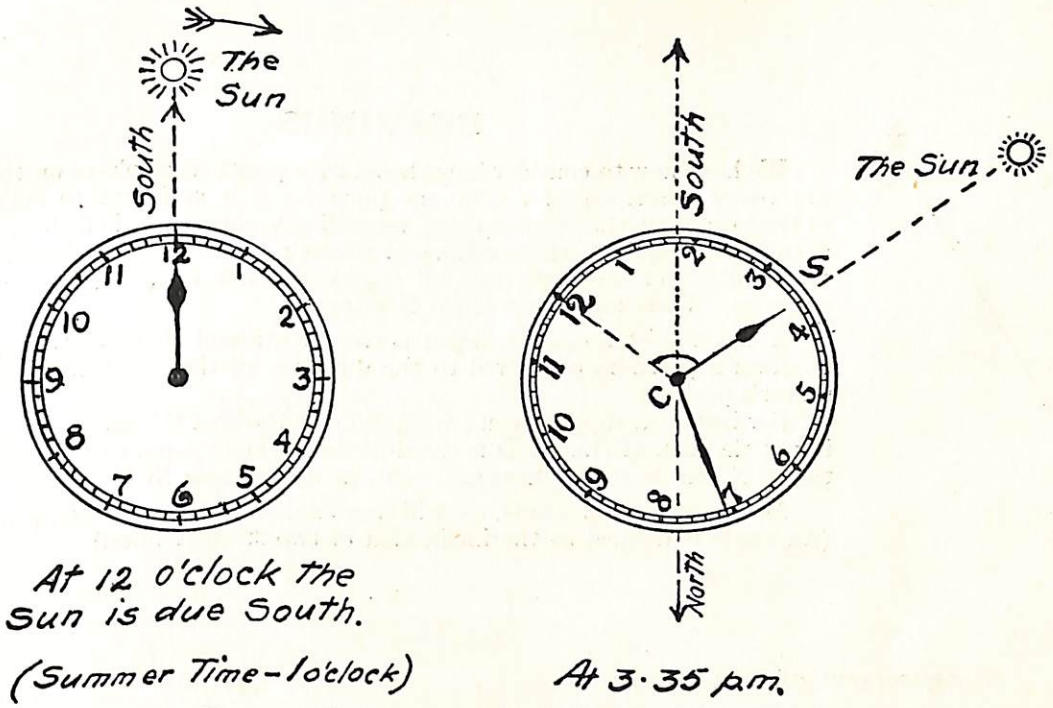


Fig. 25. Finding approximate South with a Watch

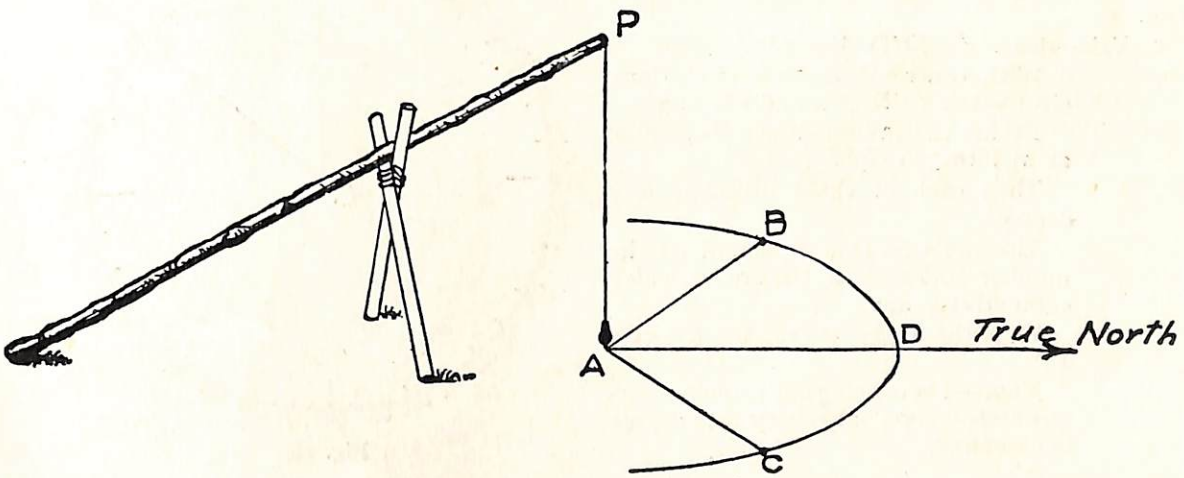


Fig. 26. Finding True North from the Sun

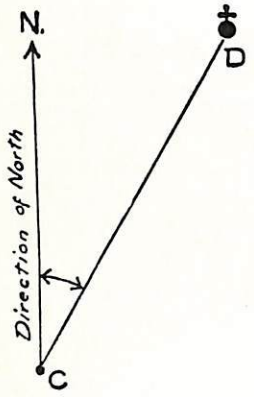


Fig. 27

BEARINGS

We have now to consider how the relative positions of places on the map are to be described; for ordinary purposes it is sufficient to make use of the points of the compass, but for military purposes, when the greatest accuracy is required, the positions of places in relation to one another and to the observer are expressed by angles and not by the points of the compass. These angles are called *Bearings*.

A **Bearing** of a distant object is the direction of that object from the observer's position, compared to the direction of the North from the observer's position.

For instance, suppose you are standing at the spot C (Fig. 27), the bearing of the distant church D is the direction CD compared to CN (pointing to the North from C). In other words, it is the angle NCD.

As a bearing is an angle, we will first explain how angles are measured. (An angle is defined as the inclination of two straight lines.)

Measurement of Angles.

Angles are measured in degrees, denoted thus °. e.g. 45°.

A Degree is $\frac{1}{360}$th part of the circumference of a circle.

1. Take the angle NCD (Fig. 28).

With centre C, draw a circle (any size) cutting CN at *x* and CD at *y*.

Divide the circumference (beginning at *x*) into 360 equal parts.

Then each of these divisions is a degree.

The angle NCD is measured by the number of degrees in the arc *xy*, which subtends the angle.

Thus the angle NCD is in this case 48°.

Note.—There being not enough space to *number* more, only every 10th degree is *numbered*.

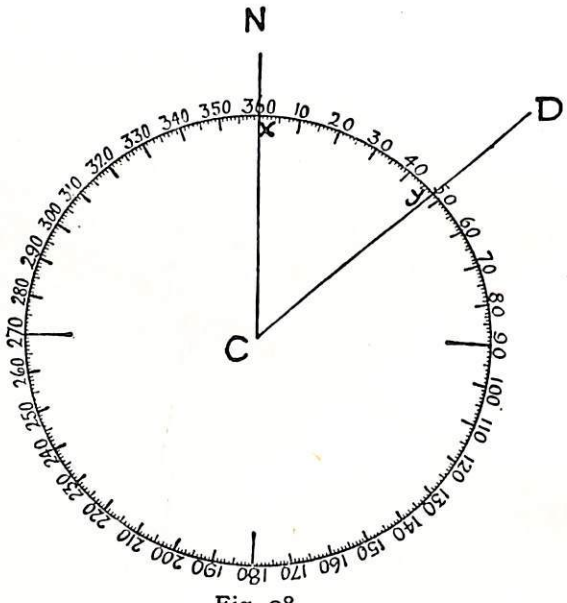


Fig. 28

2. Take the case of a right angle NCD.

It is obviously 90°, because the arc *xy* is exactly a quarter of the circumference in which there are 360 degrees.

Note.—In the diagrams given there is only room to number every 10th degree, as is generally the case with compasses. The odd degrees must be counted. Every fifth degree is usually marked rather more prominently to assist in the counting.

The plate opposite page 16 gives an idea of the size of an angle of 1°.

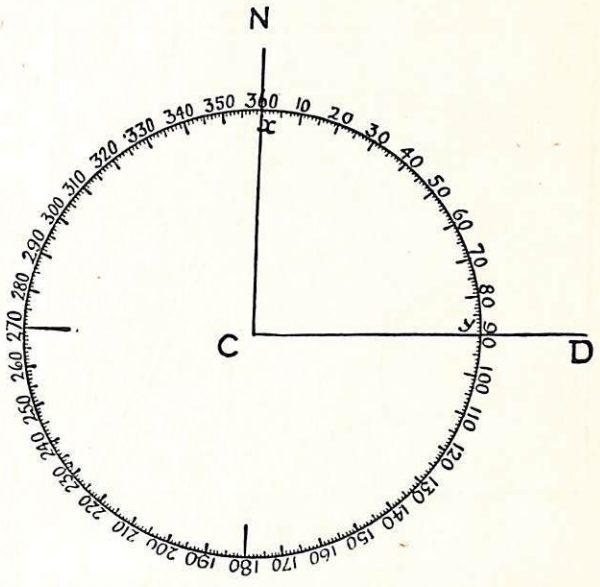


Fig. 29

3. To show that the size of the circle is immaterial, take the angle NCD and draw three circles, with C as centre, to cut both lines.

If each circumference is divided into 360 equal parts (beginning from CN) and numbered in the direction of the hands of a watch, it will be seen that the line CD cuts each circumference at the same degree, namely 125°.

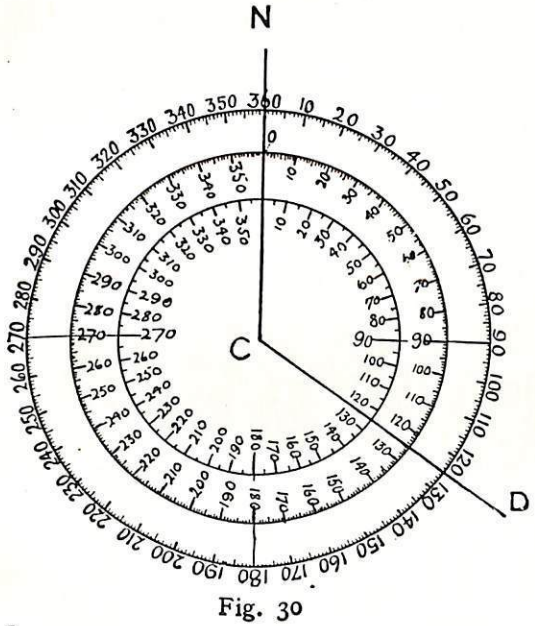


Fig. 30

There are the same number of degrees in each of the three arcs subtending the angle, but the divisions are of different sizes.

Note.—A degree may be subdivided into 60 equal parts called "Minutes" and a Minute may be divided into 60 equal parts called "Seconds." These subdivisions are for extreme accuracy and could only be shown on an enormous sized circle. For the purposes of Map Reading, degrees or half degrees are accurate enough.

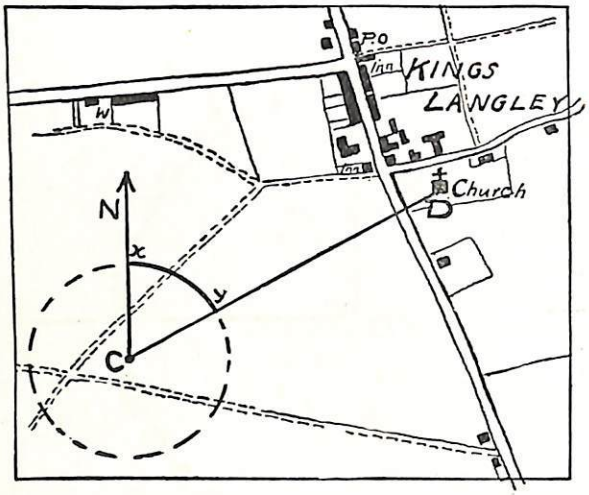


Fig. 31

MEASUREMENT OF BEARINGS

Suppose you are standing at the spot C and could see the church D at Kings Langley and you want to know the bearing.

If you drew a line CD on the ground from C directly in line with the church, and another line CN from C towards the North, then the bearing *of* the church *from* C would be the angle NCD, measured by the number of degrees in the arc *xy* of a circle drawn round C.

Bearings are measured from the North line, because it can always be found on a map and is constant. It can also be found on the ground with a compass, the variation of the compass having to be considered, however. This is explained later, after bearings are thoroughly understood.

Bearings are always measured beginning from the North Line and in the direction of the hands of a watch.

It follows that a bearing may be greater than two right angles—180°.

The diagrams below will explain.

In each case C represents the spot *from* which the bearing is taken and D the distant object.

In each case the arc which measures the angle is drawn thick with an arrow at each end.

It will be seen that if each circle were divided into 360 degrees and numbered from the North Line, the point at which CD cuts the circumference will give the number of degrees of the bearing.

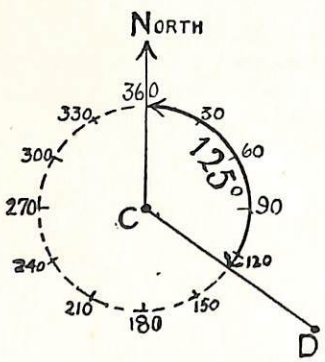


Fig. 32

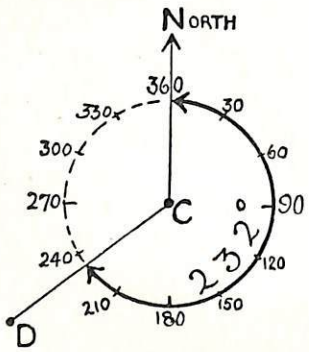


Fig. 33

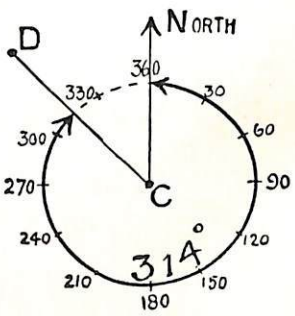


Fig. 34

The reason for measuring in the direction of the hands of a watch or clockwise.

Suppose a hungry man is standing at the point C (Fig. 35). He is told that there is an inn at a bearing of 45° from where he stands.

CN is the North Line.

If it were immaterial which way the bearing were measured, there would be *two* directions in which the inn might be, CD or CA, as NCA is also 45°, if measured from CN from right to left.

CD would of course be right, as the arc is measured from CN (the North Line) in the direction of the hands of a watch.

If the inn were at A, its bearing would be 315° (Fig. 36).

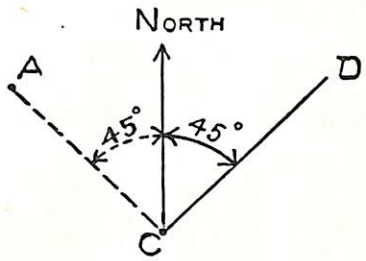


Fig. 35

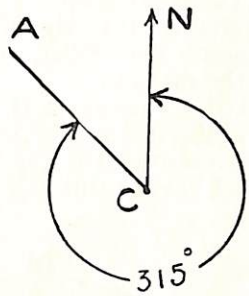


Fig. 36

Zero (0°) and 360°, it should be noted, are the same point on the circumference of the circle.

Points of the Compass. From Fig. 37, it is evident that a bearing from C due East would be 90°, South 180°, and West 270° (¾ of 360). The bearing due South is the " angle " NCS—a straight line (180°).

The nautical " points of the compass " are not much used on land, being very inconvenient. There being 32 points, the difference between them is 11¼° (Fig. 38).

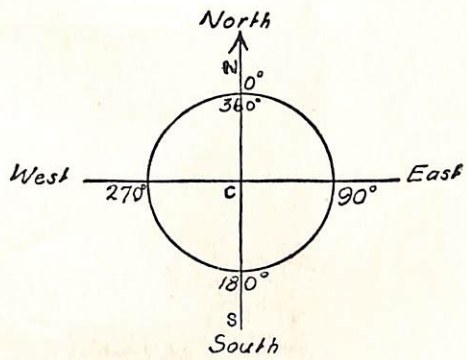


Fig. 37

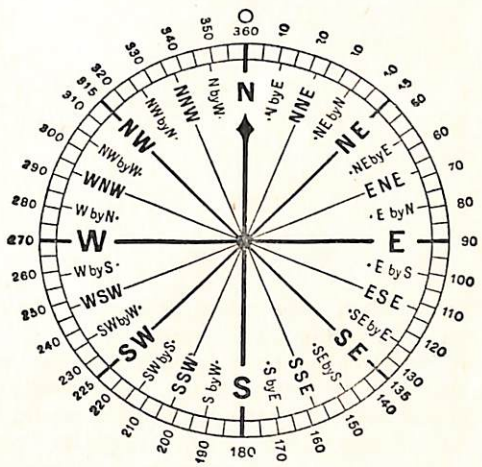


Fig. 38

Points of the Compass Compared with Degrees

The PRISMATIC COMPASS is an instrument for taking bearings. (See Fig. 22).

It contains a Dial graduated on the circumference in 360 equal parts, therefore degrees, and numbered 0 to 360 in the direction of the hands of a watch.

This Dial, which is very light, is fixed to the magnetic needle in such a position that the zero (or 360° point) on the dial is directly over the North-seeking end of the needle.

It follows that when the needle swings round to point to the North, the dial swings round with it, and when the needle settles, the 0 on the dial will be pointing (from the centre) to the North.

The centre of the dial represents the spot on which you are standing when taking the bearing.

Now in taking the bearing of say a church, D (Fig. 39) from C, suppose you had an enormous compass, with the dial fixed to the needle, and put the compass on the ground.

Then after the needle had settled with the zero (0°) on the dial pointing to the North, you stepped into the centre of the dial—C.

If you then looked at the church D, your line of vision (from the centre to the church) would cross the circumference of the dial at a certain point *y*, and the circumference being graduated and numbered, you could at once read the number of degrees in the arc between the North Line and the Line of Vision—clockwise, in this case 74°.

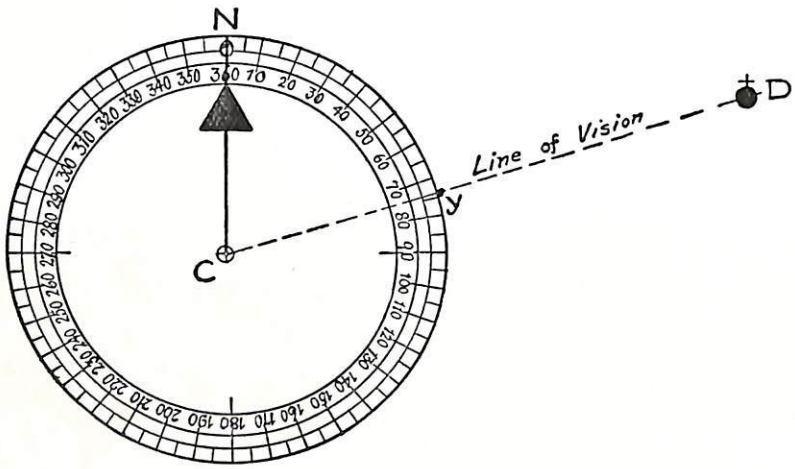


Fig. 39

This is what you want, being the bearing of the church from where you stand.

Now there is no need to stand in the centre of the dial, because if you looked *through* the centre of the dial at the church, your line of vision would be the same.

This is what you do when using the Prismatic Compass, which is held horizontally, as shown in Figure 40.

Fig. 40

You look through the slit in the prism and align the hair line in the glass of the lid (which must be vertical) on the distant object.

As the prism is directly opposite the hair line in the lid, your line of vision passes through the centre of the compass.

Figure 41 shows a bearing being taken of a distant church, and Fig. 42 is a plan of the same, showing the line of sight passing through the centre, thus forming with the North Line the angle NCD, which is the bearing of the church. The prism can be adjusted to get the correct focus.

This accommodating Prismatic Compass enables you to read the number of degrees (the bearing) at the same time as you are aligning the hair line on the distant object.

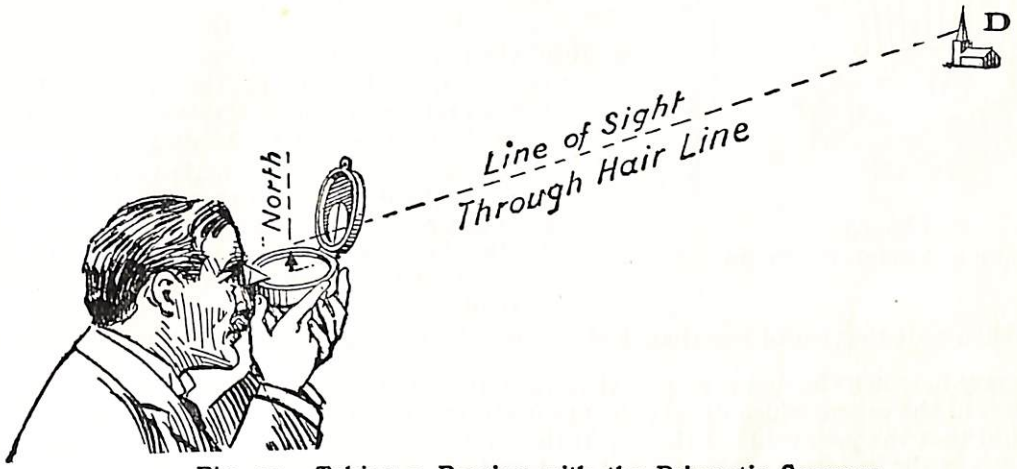
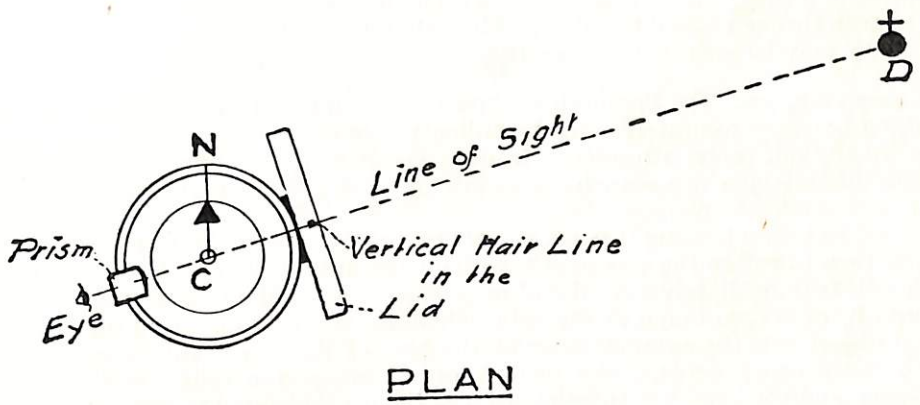


Fig. 41. Taking a Bearing with the Prismatic Compass



PLAN

Fig. 42

To take a Bearing with a Prismatic Compass.

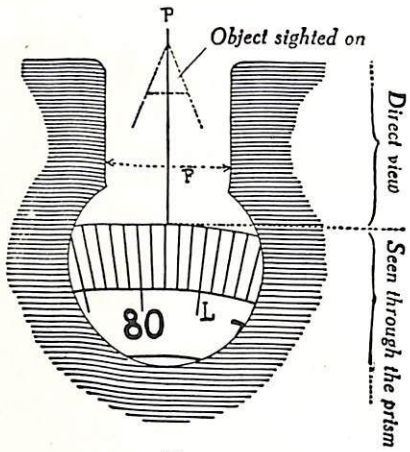


Fig. 43
Looking through the Prism

1. Hold the Compass as shown in Fig. 40, having first adjusted the prism by raising it or lowering it to focus it to suit your sight.
2. Move your body and compass round until the hair line is aligned on the distant object. The hair line must appear in the centre of the slit F on the prism. (See Fig. 43, which shows what the eye sees when taking a bearing.)
3. Allow the oscillating dial to come to rest. There is a check spring to check the oscillations, but the dial should be quite free when the reading is taken.
4. Read the number of degrees coinciding with the hair line on the dial (L) through the prism. For example, Fig. 43 represents an observation which gives 77° 50′ (nearly 78 degrees) as the reading.

Notes.—1. In the Prismatic Compass the graduations on the dial, as seen through the prism, go from *right to left*, because they are seen through a mirror. In the Lensatic Compass (and others), described on page 90, they are seen through a lens, so go from left to right.

2. When a distinction of less than ¼ of a degree is desired, the compass must be supported.

The way in which the dial is read in the Prismatic Compass is by means of a small mirror in the lower part of the prism, which directs the vision straight down on the edge of the dial. Now it will be noticed that the prism side of the dial is the wrong side of the dial, as you want the number of degrees where the line from the centre to the distant object cuts the circumference—which **is** exactly *opposite* the prism.

Therefore, in the Prismatic Compass a second ring of figures is marked on the dial to correspond with the number of degrees directly opposite. This is the *outer* ring of figures and they are inverted and appear as seen through a looking-glass. They are only for use when reading a bearing through the prism. They may be seen in Fig. 100, page 66.

The Ordinary Compass. The Prismatic Compass has been mentioned first because it is essentially made for taking bearings accurately. In the ordinary compass the needle only oscillates and points towards the North, and there is no dial. In most compasses the circumference of the *base of the box* is marked off into 360 degrees, the zero (0°) or 360° point being opposite the ring handle, if any.

In this case, to take a bearing it is necessary first to let the needle come to rest pointing towards the North and then to rotate the box gently without disturbing the needle until the north-seeking end of the needle is immediately over the 0° or 360° division on the base of the box. The bearing of the distant object is then found at the point where the line of vision from the centre of compass to the distant object cuts the circumference of the base of the box. This is very difficult to read accurately, because when sighting the distant object across the centre of the box you cannot read the bearing, and the head has to be raised and the needle is very sensitive to movement.

The Near Presence of Iron **affects a Compass.** (See page 24.)

The **PROTRACTOR** is a flat piece of wood, celluloid or other material with the centre marked thereon and with the edge graduated to give degrees. It enables you to—

1. **Plot bearings:** i.e. draw on paper or on a map a given bearing from any point.
2. Read bearings on a map. In other words, you can find what is the bearing from a particular spot of any distant object, such as a village, church, cross roads, etc., shown on the map.

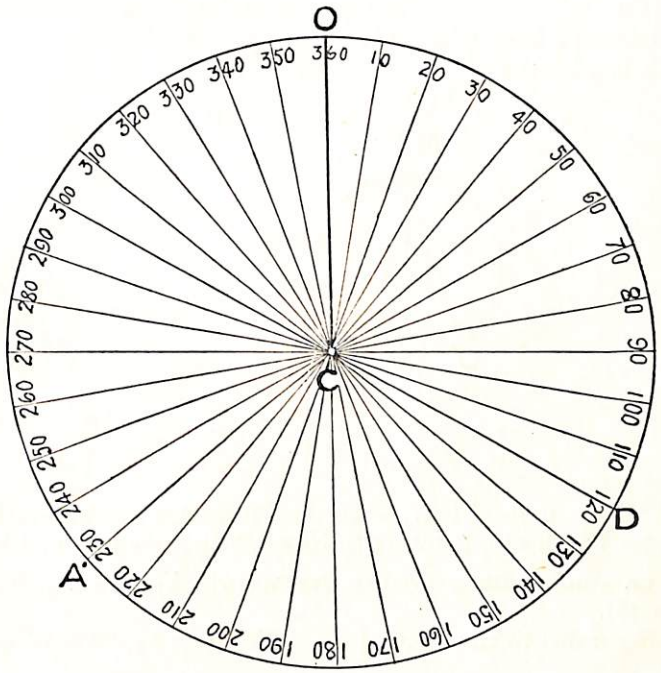


Fig. 44. A Circular Protractor

The Shape of a Protractor. The Service Protractor is oblong and will be explained later, but the simplest form (and the best for the purpose of explanation) is a circular piece of transparent celluloid, with a pin-hole in the centre and graduated round the edge in 360 degrees, in a precisely similar manner to the compass dial.

In the diagram (Fig. 44) only every 10th degree is shown and numbered.

If we consider CO as the North line of a compass dial it will be seen that the bearing of D from C, or the angle OCD, is 120°—similarly the bearing of A from C is 230°.

In using a Protractor for bearings, it is always placed on the map so that its centre is exactly on the spot representing the point from which the bearing was taken or is to be read: and the line from the centre to 0° or 360° is always placed along a line drawn from the same point towards the North or parallel to such a line

To draw a bearing with a Circular Protractor of, say, 220° from a point C on a map.

1. Draw a fine pencil line from C towards the North. All maps have a North Line on them, so that this line is drawn parallel to it (Fig. 45).
2. Place Protractor over the point C and put a pin through the centre and into the paper at the point C (Fig. 46).
3. Circulate Protractor until the zero (0°) or 360° is on the North Line you have drawn.
4. Make a fine point D on the map directly opposite the 220th degree.
5. Remove Protractor.
6. Join CD and produce to E (any distance) (Fig. 47).
7. Then the line CE is a bearing from C of 220°.

Fig. 45

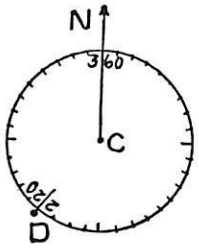


Fig. 46

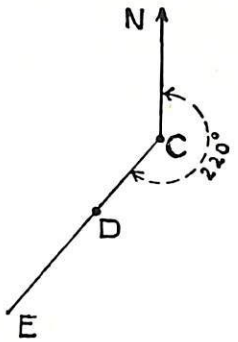


Fig. 47

Note.—It will be noticed that, when the Protractor was in position, it was just like the dial of a compass with zero pointing to North, being swung round by the magnetic needle.

To read a bearing on a map with a Circular Protractor. You want to read the bearing *of* the church D *from* A (Fig. 48).

1. From A draw AN parallel to the North Line. (See page 84, "Hints on Drawing.")
2. Join AD.
3. Place Protractor on map as above, with centre over A and zero or 360° on AN (Fig. 50).
4. Then the point where AD cuts the circumference or rim of Protractor will give you the number of degrees of the bearing of D *from* A, namely 320°.

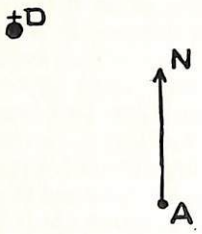


Fig. 48

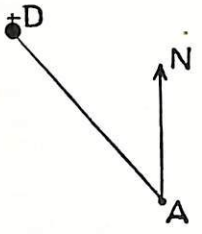


Fig. 49

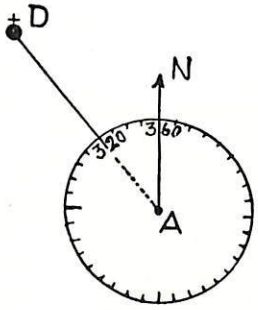


Fig. 50

Note.—If D were so close to A as to be covered by the Protractor when placed on top, it would be necessary, after joining AD to produce the line.

The SERVICE PROTRACTOR is, however, not circular, and it is made of ivorine.

Now suppose we cut the aforementioned circular Protractor in half, down the North to South line (Fig. 51), or from 0° to 180°. We could then use it for bearings up to 180° by placing the centre of Protractor (C) against the point on the map from which the bearing was taken, and the zero (0) on the North Line from that point.

Now any part of each line radiating from the centre would give the bearing as marked at the circumference of that line.

Therefore, suppose, after marking on the lines, we cut the half protractor into an oblong (Fig. 52) and number each of the lines at the edges the same number as at the circumference (Fig. 53). Then the oblong Protractor can be used up to 180° just as easily as the circular one. We have only shortened some of the lines—the angles are the same.

This is the shape of the Service Protractor.

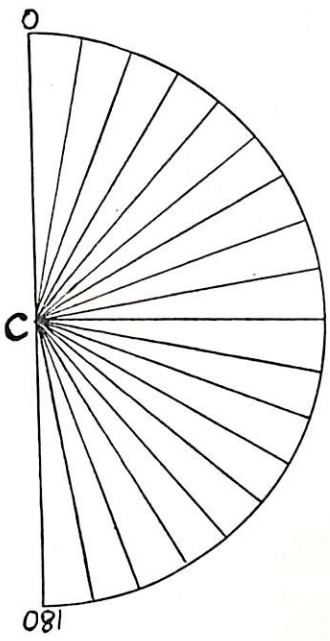


Fig. 51

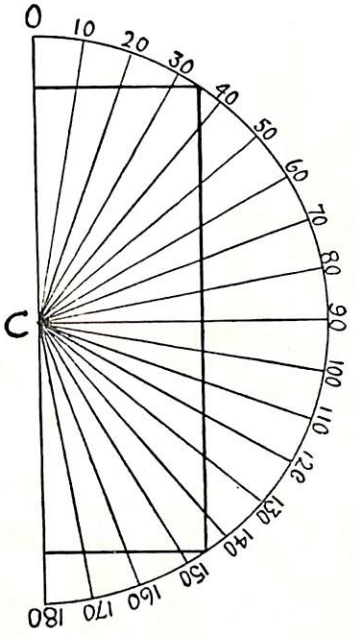


Fig. 52

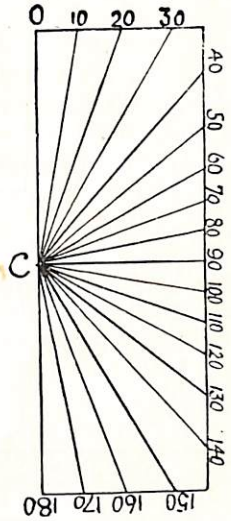


Fig. 53

The Making of an Oblong Protractor

Now as only the graduations on the *edges* of the Protractor are used, the lines are not shown running from the centre, but only short ones at the edges, and the centre of the Service Protractor is marked by an arrow head (Fig. 54).

In using it we must remember that the point of the arrow is the centre of the Protractor (originally circular) and corresponds with the centre of the Compass. This leaves room on the Protractor for some useful scales.

Now if we had similarly treated the other half of the Protractor, it would appear as in Fig. 55, the 360 degree corresponding with the 0° in the other half.

In using this half, the arrow head (or centre) would be placed on the spot from which bearing was taken and the 360° on the line running from that spot to the North.

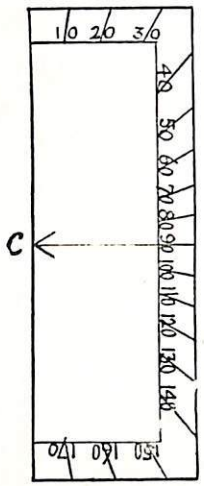


Fig. 54

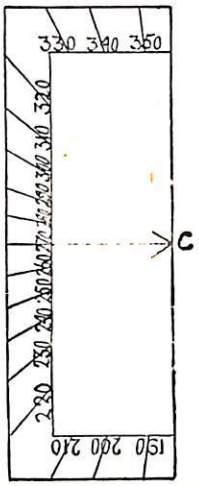


Fig. 55

Now as the divisions at the edges on the two halves are precisely similar, the Service Protractor is made of one half only but numbered at the edges with *two sets of figures*, as shown in Fig. 56, which is a full size reproduction of the Service Protractor.

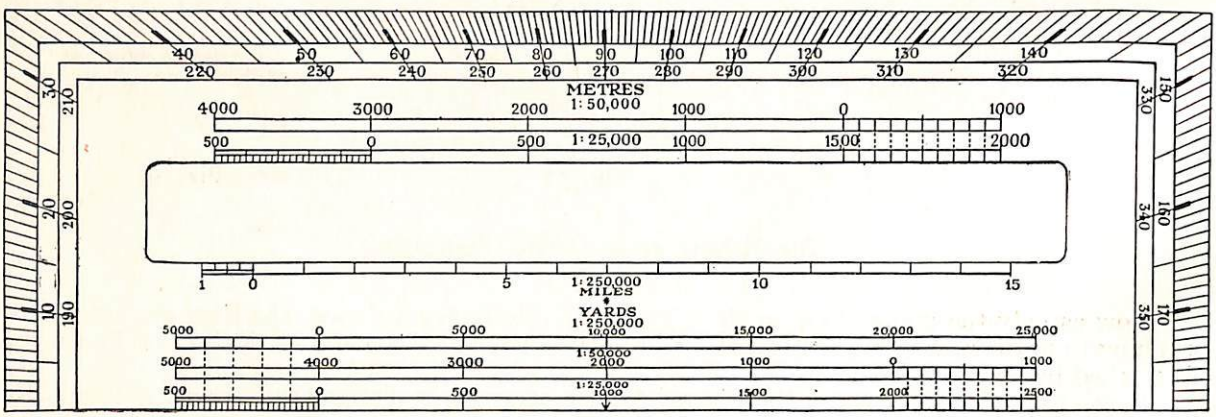


Fig. 56. The Service Protractor (Full Size)

The outer set of figures is used for plotting or reading bearings up to 180°, by putting zero 0° on the line running from the point to the North.

The inner set of figures is used for plotting or reading bearings over 180°. In this case 360° must be put on the North Line, and this will be observed to be the other end of Protractor.

Using the Oblong Protractor. (1) For bearings under 180°, it will be noticed that the Protractor is placed on the *right* of the line from the observer's position to the North. If the North were towards the *bottom* of the map the map should be turned round so that the direction of the North is away from you and the same rule would apply. For bearings over 180° it is placed on the *left*.

(2) In using the oblong Protractor it is best to draw the line to the North *right through* the observer's position C instead of simply *from* C, because it makes it easier to place the Protractor in its exactly correct position along this line—an important point.

To Draw a Bearing under 180° with Service Protractor. Required to plot a bearing of 65° from the spot C (Fig. 57).

1. Draw a fine pencil line CN through C parallel to the North Line given on the map. (*Note*—The North is usually to the top of the map but not necessarily.)
2. Place the Protractor on the map with the centre (arrow head) at the point C and the edge along CN, so that the zero (0°) is on the line CN running from C to the North (Fig. 58).
3. Make a fine mark (D) on the paper at the edge of the Protractor opposite the 65° graduation.
4. Remove Protractor.
5. Join CD and produce to E (Fig. 59).

Then the line CE is a bearing of 65° from C (i.e. the angle NCD=65°).

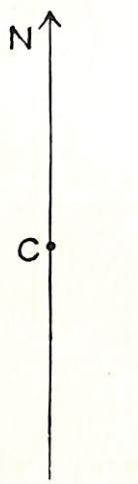


Fig. 57

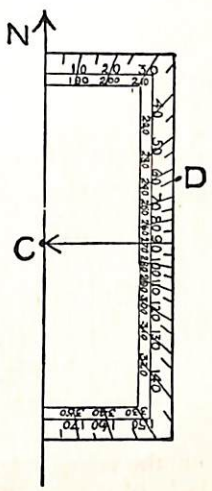


Fig. 58

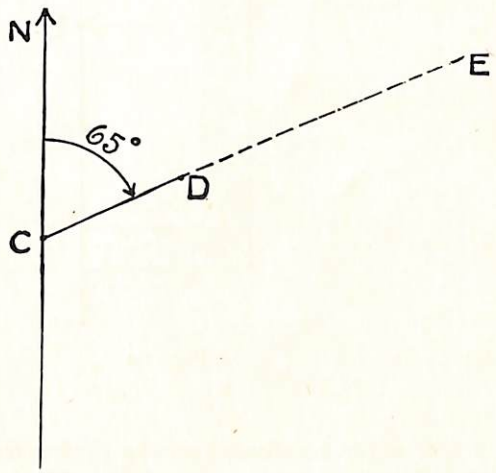


Fig. 59

To Draw a Bearing over 180° with Service Protractor—say 320°.

1. Draw a line CN through C parallel to the North line (Fig. 60).
2. As it is over 180° we must use the *inner* set of figures and ignore the outer set, so place the arrow head at C and the 360° on the line from C to the North (Fig. 61).
3. Mark the point D on the map opposite the 320° division.
4. Remove Protractor.
5. Join CD and produce to E (Fig. 62).

Then CE is a bearing of 320° from the point **C.**

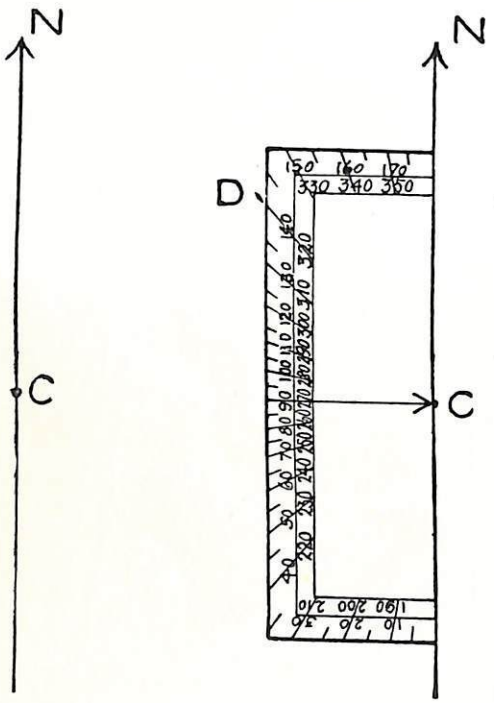


Fig. 60

Fig. 61

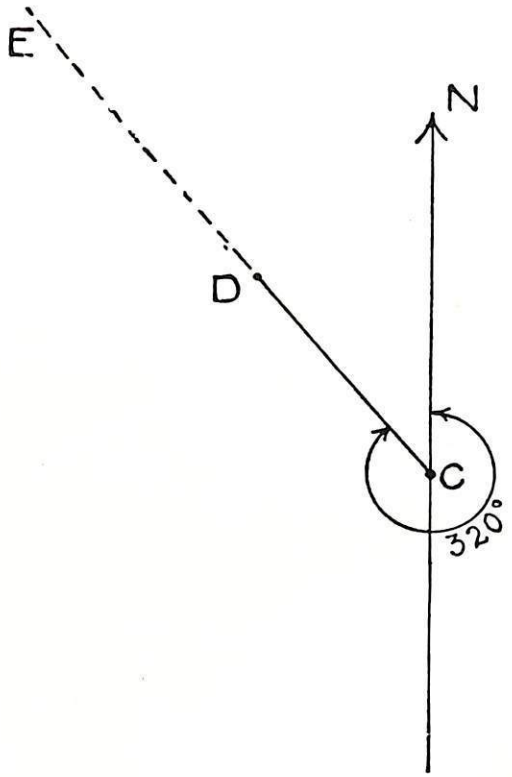


Fig. 62

The 360° is not numbered on the Protractor, being on the edge, but it is easy to tell which end it is, being of course next to the 350° graduation. Similarly 0° is next to 10° at the other end of the Protractor. If you were to place two Protractors along the line, one on either side and with the arrowheads on C, you would get the whole 360°, using the outer set on the right and the inner set on the left.

To Read a Bearing under 180° with Service Protractor. Required to find the bearing *of* Thurne Church from Ludham Bridge on the map (Fig. 63).

1. Through the centre of the bridge draw a pencil line parallel to the North line.
2. Draw a pencil line from centre of bridge to the church.
3. Place Protractor on map with arrow head at the centre of the bridge and with the edge along the North line, so that 0° is on the line from the bridge to the North Fig 64.
4. Read off the bearing required at the point where the line from the bridge to the church cuts the edge of the Protractor, viz. 116°—the *outer* set of figures.

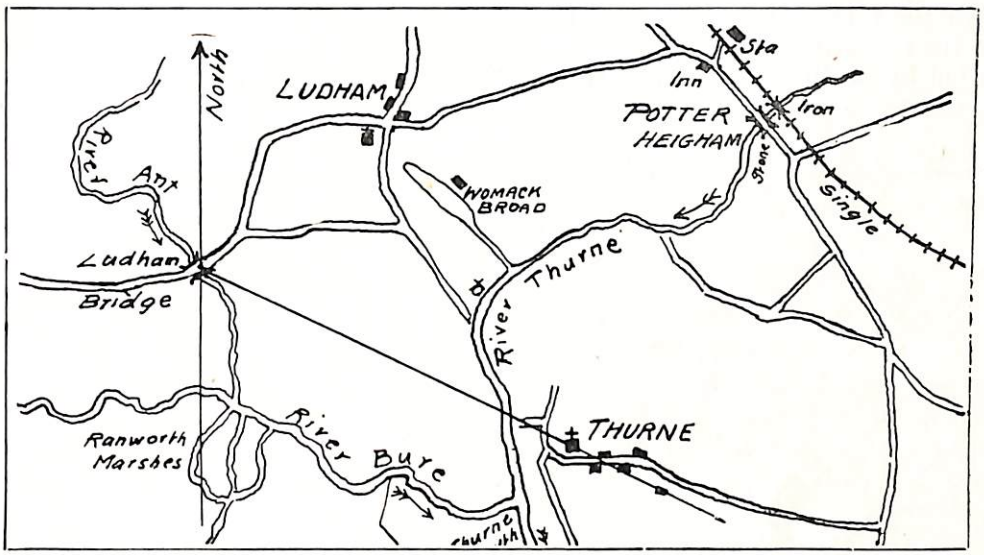


Fig. 63

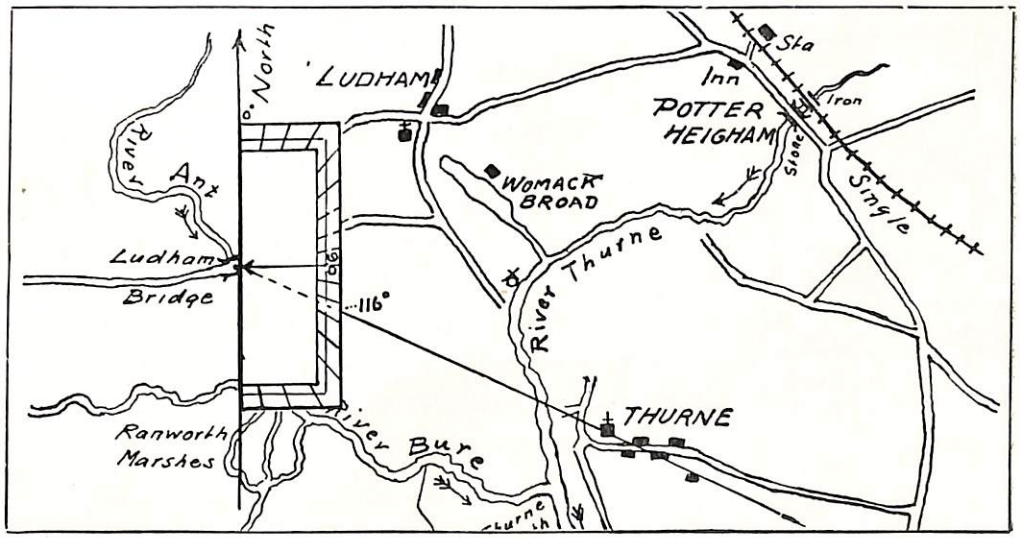


Fig. 64

To Read a Bearing over 180° with Service Protractor. Being a foggy day and having to row from the boathouse (C) to the staithe (D), you require to find the bearing of the entrance of the staithe from the boathouse.

1. Draw a line, CN, through C parallel to the North line (Fig. 65).
2. Join CD.
3. Place Protractor with arrow-head at the boathouse C and with the edge along the North line CN so that the 360° is on the line from C to the North. (If the North is to the top of the map the Protractor will be on the left). (Fig. 66.)
4. Read the required bearing (the *inner* set of figures) at the point where the edge of Protractor is cut by the line running from the boathouse to the staithe, viz. **275°.**

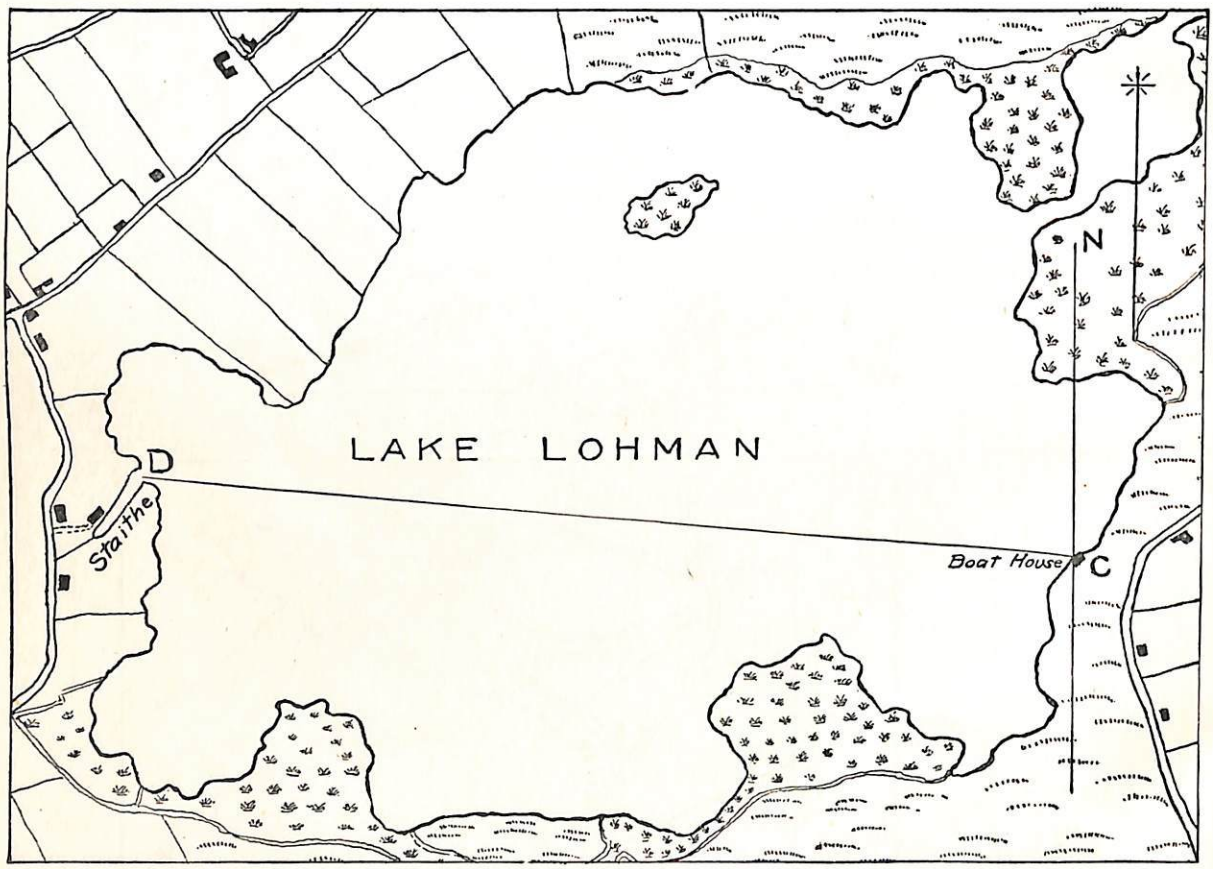


Fig. 65

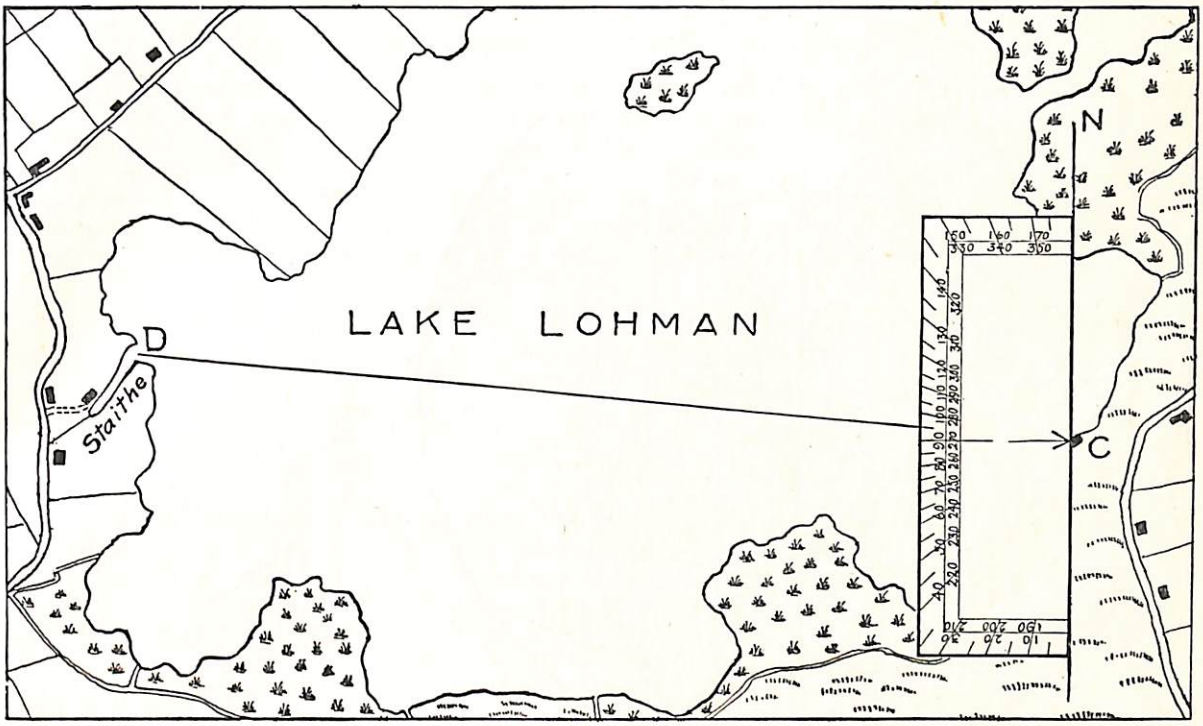


Fig. 66. Reading a Bearing over 180°

A WATCH USED AS A PROTRACTOR

The watch must be placed with the centre directly over the spot from which the bearing is required. To do this draw a True North and South line through the spot and one at right angles—East and West. By moving the watch about, so that 12 o'clock and 6 o'clock coincide with the North-South line and 9 o'clock and 3 o'clock with the West-East line, the centre of the watch will be directly over the spot.

Each *minute* division will represent 6° as there are 60 *minute* divisions in the 360° of the circumference. Thus NCP is 72°.

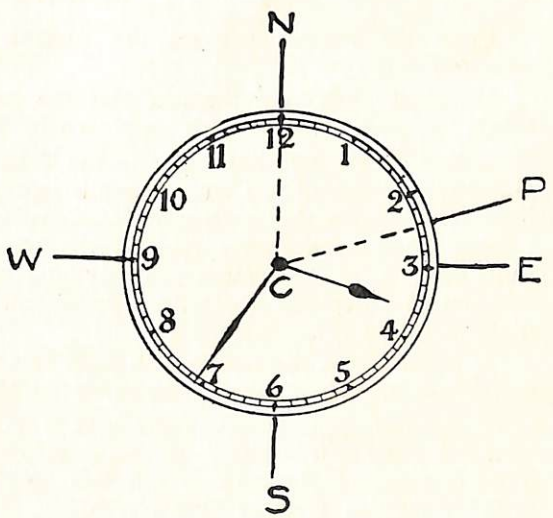


Fig. 66A

TRUE NORTH AND MAGNETIC NORTH

We have gone very fully into the subject of Bearings and the use of the Protractor, having experienced that many students find the greatest difficulty in clearly understanding them.

In explaining them, to avoid confusion, we have so far simply used the expressions "North" or "North line." The next few pages explain "*True North*," "*Magnetic North*" and "*Grid North*"—also "*True Bearings*" and "*Magnetic Bearings*"

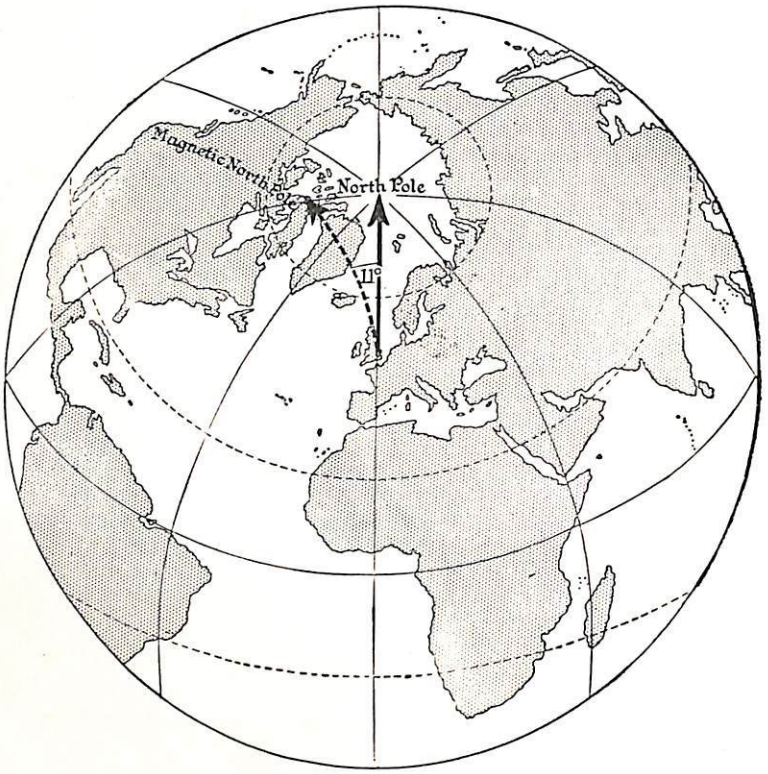


Fig. 67. Showing the North Pole and the Magnetic North Pole

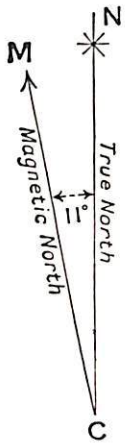


Fig. 68

MAGNETIC VARIATION

From the preceding pages the student should now know what a bearing is and how it is measured.

He must now grasp the fact that the needle of a Compass does not point exactly to the True North, or Geographical North, as shown by the meridians on maps.

A line drawn from any point to the True North would point in the direction of the North Pole, whilst the needle of a Compass points in the direction of the *Magnetic North Pole*, which is under Boothia Land, on the north coast of Canada.

Fig. 67 shows both the True North Pole and the Magnetic North Pole, and shows the direction from London of True North and Magnetic North, making an angle of approximately 11°. (In the drawing the Magnetic North line appears curved owing to the spherical shape of the earth, but it is really pointing in a straight line.)

It follows that the needle will point at a varying angle to the True North line at different parts of the world. This angle is known as the **Magnetic Variation** and is measured in degrees.

For example, suppose C represents a spot in London and CN is the True North line. The compass needle will point in the direction CM (Magnetic North), and the angle NCM between True North and Magnetic North will be the Magnetic Variation which in this case—in London is 11° West (i.e. West of True North).

MAGNETIC VARIATION

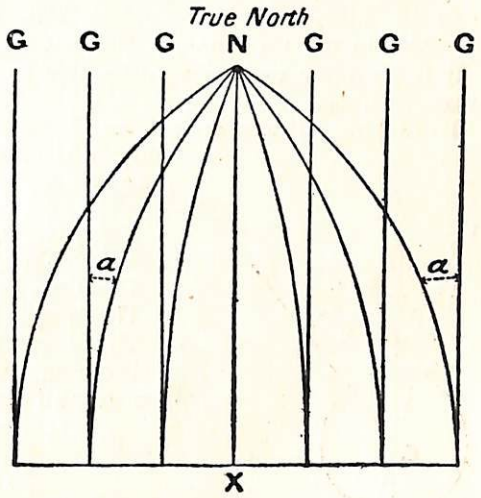
In some parts of the world (e.g. Western Canada and parts of Asia) the Magnetic North is *East* of True North. The Magnetic Variation can be obtained from Magnetic Charts, and as it changes slightly annually it is important to obtain the actual Variation at the time of using the map.

On some maps the Magnetic Variation for a particular year is shown by linking together all points having the same Variation to form continuous lines. Thus, on a map of England if all points having the same Variation, respectively, of 10°, 11°, 12°, 13°, and 14° were joined together, five curving continuous lines running roughly parallel to one another would result. Such lines are known as "Isognals." The extent of the variation in degrees, and the year to which the figures relate, are printed at intervals along the isognals.

Grid North.—Grid North is the direction in which the Grid lines point towards the top of the map.

To be of value on military maps the Grid must be rectangular, and it will be seen from Fig. 69 Grid North lines cannot everywhere point to True North as do the Meridians.

It is usual to make one Grid line coincide with a Meridian. On this standard Meridian (usually in the middle of the map), the Grid line points to the True North. All other vertical Grid lines are drawn parallel to it, and do not point exactly to True North but to an imaginary "Grid North." In the case of England the difference is very small, as is shown in Fig. 136, page 91. The angle between Grid North and True North is known as "the angle of convergence"—the farther the map sheet is from the Standard Meridian the greater the angle.



NX Standard Meridian
N North Pole
G Grid North
A Angle of Convergence

Fig. 69

COMPASS ERROR

The Magnetic North is the direction to which a perfectly made compass would point, but, owing to some slight defect in manufacture or through wear and tear, compasses sometimes have a slight deviation of their own, say 1½° West, or say 2° East of Magnetic North.

This is known as your Compass Error and must be taken into account.

A good instrument maker will "calibrate" your compass, i.e. give you the error in degrees to be added to or subtracted from the Magnetic Variation. On page 88 in the Appendix is shown how to find your Compass Error, if any, yourself.

Magnetic Variation is the variation between True North and the direction in which a *true* compass points. Whilst the variation between True North and your own compass is spoken of as your *Compass* Variation ; the difference between them, if any, being your Compass Error.

MAGNETIC BEARINGS AND TRUE BEARINGS

Now as we have explained that there are *two* North directions, namely True North and Magnetic North, so must there also be two kinds of Bearings—True Bearings and Magnetic Bearings.

A True Bearing is the measurement of the angle between the True North line and the line from the observer's position to the distant object.

A Magnetic Bearing is the measurement of the angle between the Magnetic North line and the line from the observer's position to the distant object.

Both measurements are reckoned from the North line clockwise. When you take a bearing with a compass, it is, of course, a Magnetic Bearing.

In all military operation orders *True* Bearings or *Grid* Bearings are always given, owing to differences in the variations of different compasses.

It is therefore necessary to be able to convert True Bearings into Magnetic Bearings, and vice versa—with ease.

To do this, always *draw a rough diagram* similar to the examples given on pages 50 and 51. You can then see exactly what you are doing and it makes the problem quite simple.

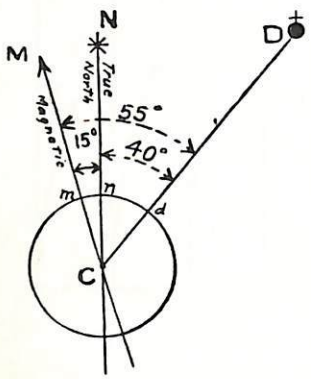


Fig. 70

Fig. 70. Suppose C is the observer's position and D a distant church CN is the True North line and CM the Magnetic North line.

The True Bearing of the church from C is the angle NCD, say 40°.

The Magnetic Bearing of the church is the angle MCD, say 55°.

The Magnetic Variation is the difference, namely the angle MCN—15°.

From this, when the Magnetic Variation is *West* of True North, as it is in nearly all over Europe, we get the formula:

Mag. Bearing = True Bearing + Mag. Variation.
or True Bearing = Mag. Bearing − Mag. Variation.
or Mag. Variation = Mag. Bearing − True Bearing.

It will perhaps make it perfectly clear if we remember that the Magnetic Bearing is measured by the number of degrees on the arc *md*, the True Bearing by the arc *nd*. So the Magnetic Variation is the number of degrees in the arc *mn* (*md* = *nd* + *mn*).

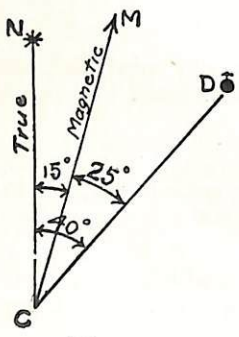


Fig. 71

In some parts of the world (Western America and parts of Asia) the compass points to the *East* of True North and the Compass Variation is given as so many degrees *East*.

In this case, if the True Bearing of the church D from C is 40° and the Magnetic Variation is 15° *East*, then the Magnetic Bearing will be the angle MCD (Fig. 71), which is 40° − 15° = 25°.

Thus when the Variation is *East* of True North, we get the formula:

Mag. Bearing = True Bearing − Mag. Variation.

There is no need to remember these formulæ if you always draw a rough diagram as in the examples that follow; drawing the Magnetic North to the *left* of True North when the Variation is West, and to the *right* of True North when the Variation is to the East.

The Protractor may be used for reading or drawing either True Bearings or Magnetic Bearings. *

For True Bearings it must be placed along the True North line.

For Magnetic Bearings it must be placed along the Magnetic North line.

As an example, in Fig. 72, P is a point on the map and a distant church is shown to the right.

Through P draw a True North line and also a Magnetic North line (supposing the Magnetic Variation to be 15° W.).

Draw a line from P to the church.

You can then read the True Bearing of the church from P–90° by placing the Protractor along the True North line (Fig. 72).

Or you can read the Magnetic Bearing by placing it along the Magnetic North line—namely, 105° (Fig. 73)

It will be noticed that the Magnetic Bearing 105°=90°+15°.

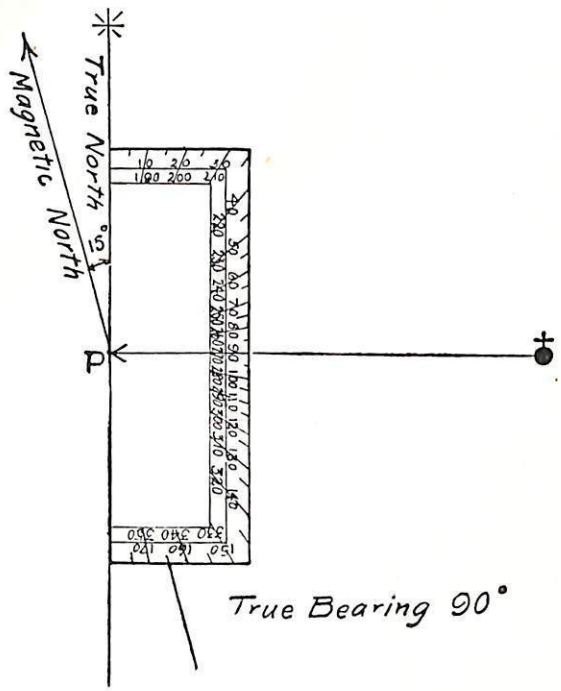


Fig. 72

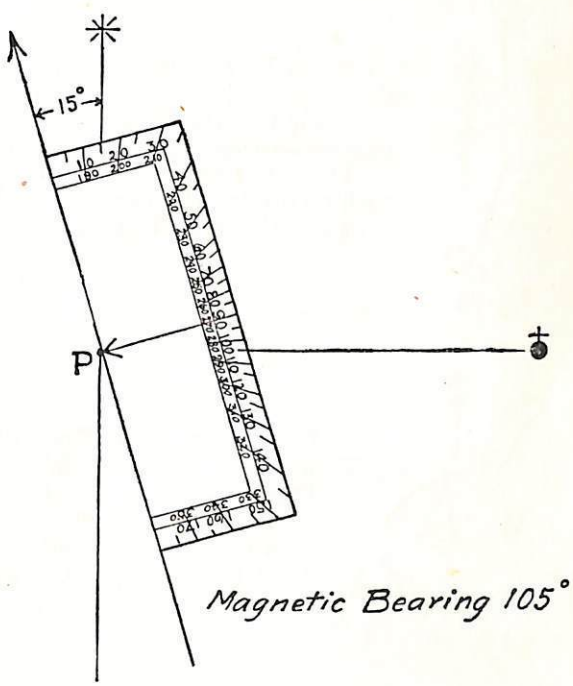


Fig. 73

Sketches of a piece of country are often made from Magnetic North lines, the True North line being put on the map afterwards. This saves the trouble of converting all the Compass Bearings into True Bearings.

*Or Grid Bearings. Indeed, when included in messages and reports, most bearings are given in "grid" bearings (see pages 90-92). In the example above, if a grid map were being used it would be more convenient to draw the N–S line through P parallel to the nearest N–S grid line. The angle formed by the True N–S and Grid N–S is always shown on gridded maps, and it is an easy matter to calculate from the "grid" bearing the appropriate True North and Magnetic North Bearings.

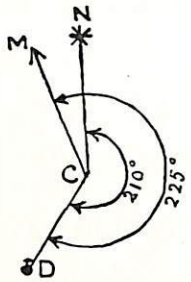


Fig. 74

CONVERTING BEARINGS

Example 1. The True Bearing of a distant church D from the point C is 210°. Its Magnetic Bearing from C is 225°. What is the Magnetic Variation?

Make a rough diagram, drawing CN the True North line, and draw CD to represent the True Bearing of the church, and draw in the arc 210°.

Now as the Magnetic Bearing is greater than the True Bearing, the Magnetic North line must be to the left or West of the True North line, so draw CM to represent Magnetic North to the left of CN.

Draw another arc with arrows to show the Magnetic Bearing is 225°.

Then the Magnetic Variation MCN is obviously 225°—210°=15° West.

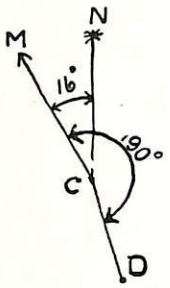


Fig. 75

Example 2. The Variation of your Compass is 16° West. The Magnetic Bearing of a point D *from* C is 190°. What is the True Bearing of D from C?

Draw CN True North line and CM Magnetic North to the left (or West) of CN to represent an angle of 16° and mark it so.

Draw CD to represent Magnetic Bearing (from CM) of 190° and mark it so with an arc with arrows.

Then the True Bearing (NCD) is obviously 190°—16°=174°.

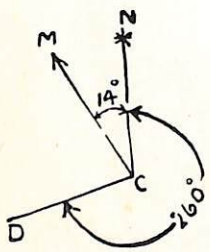


Fig. 76

Example 3. The True Bearing of a point D from C is 260°. Magnetic Variation is 14° West. What is the Magnetic Bearing of D from C?

Draw CN True North and CM Magnetic North to the West of CN to represent the angle of 14° and mark it so. Draw CD to represent True Bearing (from CN) of 260° and mark it so with an arc with arrows.

Then the Magnetic Bearing is obviously 260°+14°=274°.

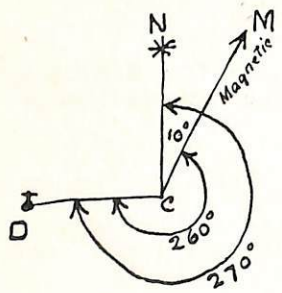


Fig. 77

Example 4. The True Bearing of a distant church D, from the point C, is 270°. The Magnetic Variation is 10° East.

What is the Magnetic Bearing of the church?

Draw a line CN to represent True North and draw CD to represent the True Bearing of 270°, and mark the angle with arrows.

Now as the Variation is *East*, draw CM to the *right* of CN to represent Magnetic North.

Then the Magnetic Bearing is evidently 270°—10°=260°.

CONVERTING BEARINGS

Grid Bearings. On a gridded map all Bearings must be with reference to Grid North and not to True or Magnetic North. Gridded maps show in the margin the angle between Grid North (Fig. 78), with an additional note stating the angle between Grid North and True North for that sheet. This enables the user to convert the Bearing with reference to Magnetic or True North to Grid North.

In the foregoing examples of converting Bearings, if CN were Grid North instead of True North, they would apply equally well for Grid Bearings instead of True Bearings.

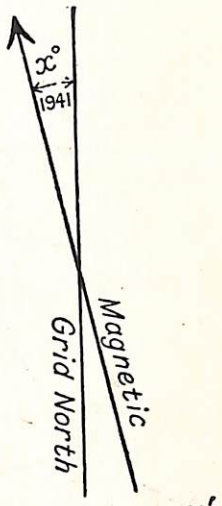


Fig. 78

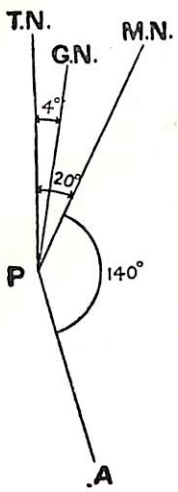


Fig. 79

Example 5.

Compass Variation 20° East.
Grid North is 4° East of True North.
Magnetic Bearing A from P is 140°.
What is the True Bearing and Grid Bearing?

True Bearing $= 140 + 20 = 160$.
Grid Bearing $= 140 + 20 - 4 = 156$.

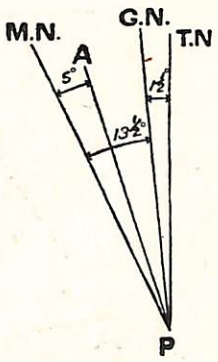


Fig. 80

Example 6.

Magnetic North is 13° 30′ West of Grid North.
Grid North is 1° 30′ West of True North.
Magnetic Bearing from A to P is 5°. Compass correct.
What is the True Bearing and the Grid Bearing?

Magnetic Variation $13\frac{1}{2}^\circ + 1\frac{1}{2}^\circ = 15^\circ$ W.
True Bearing $365^\circ - 15^\circ = 350^\circ$
Grid Bearing $350^\circ + 1^\circ 30' = 351^\circ\ 30'$

or from diagram direct:

Grid Bearing $365^\circ - 13\frac{1}{2}^\circ = 351^\circ\ 30'$

INTERSECTION

LOCATING THE FLASH OF A GUN

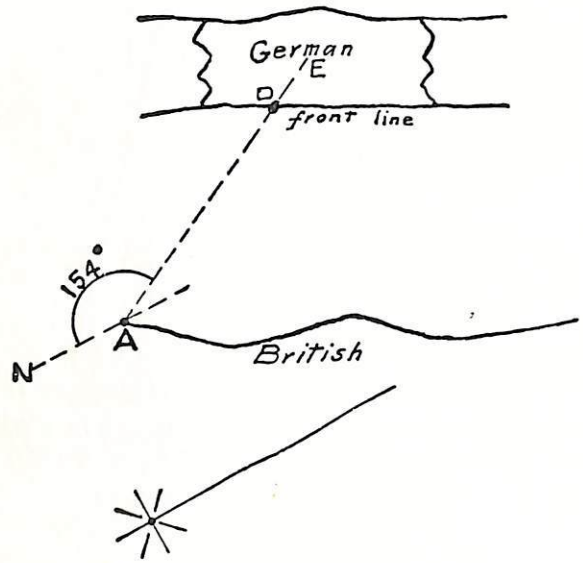


Fig. 81

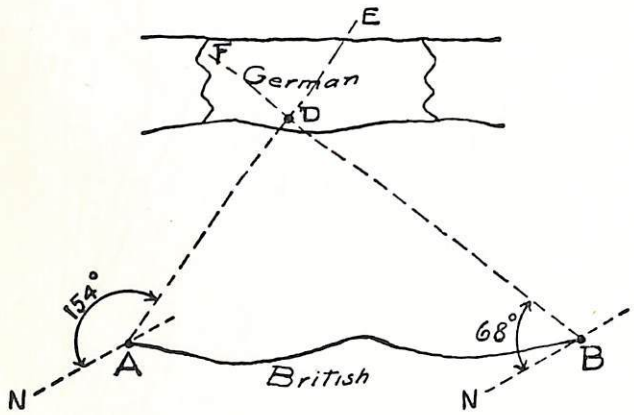


Fig. 82

You are standing at the point A in a British trench and a flash is seen in the German front line. (Note the direction of True North.) (Fig. 81.)

(*a*) 1. Take Compass Bearing of the flash, say 170°.

2. Suppose Compass Variation is 16° W.

3. Then True Bearing is 154° W.

4. On the map draw True North line AN and set off the bearing AE of 154° with the Protractor.

Then where AE strikes the German front line (at D) on trench map is the position of the flash.

(*b*) When the flash cannot be definitely located in the front line or any given line of trench two bearings will be necessary (Fig. 82).

1. Take bearing from A and draw AE on map, as above.

2. Go to B, which you locate on map.

3. Wait for another flash and take the bearing from B, say 84°.

4. Then True Bearing is 84°—16°=68°.

5. On the map draw a True North line BN and from B draw the bearing (BF) of 68°.

Then where BF crosses AE at D is the position of the flash.

Note.—B should be chosen so that the angle BDA is approximately a right angle.

This is called finding a point by Intersection. Maps are often made on a "Plane Table" on this principle.

BACK BEARINGS

Bearings such as we have described are sometimes called " forward bearings."

Suppose you are standing close by the tree at C (Fig. 83). You take a Compass Bearing of distant church D. You can then tell the Compass Bearing *of the tree from the church* without going to the church to take it. The latter bearing is called the back bearing of the church.

The difference between the two is always 180°. Thus if the forward bearing of the church were 60° the backward bearing would be 60°+180°=240°.

Fig. 84 will explain why this is. Draw Magnetic North lines through C and D and join CD and produce to E.

The forward bearing of the church is angle MCD. The backward bearing is the angle M^1DC.

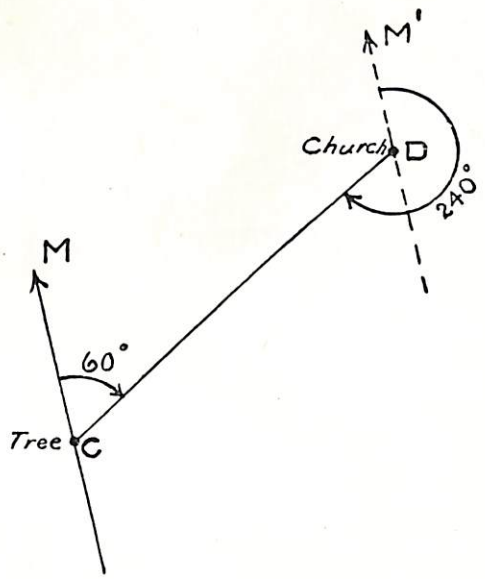


Fig. 83

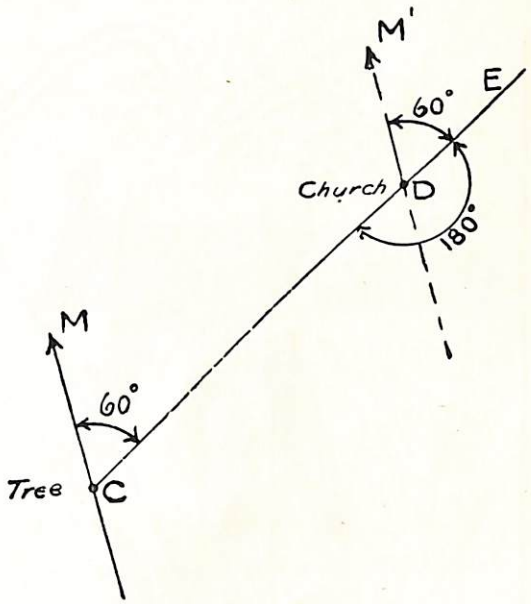


Fig. 84

Now those who remember their Geometry will know that as MC is parallel to M^1D, the angle MCD=M^1DE, so that the difference between the forward and back bearings is the number of degrees in a semicircle, which of course must be 180°.

Similarly, if the church D were the observer's position the forward bearing of the tree would be 180° *more* than the back bearing.

The Rule therefore to get the back bearing is this: If the forward bearing is under 180° add 180°. If the forward bearing is over 180° deduct 180°.

If the forward bearing were exactly 180° it would be due South and by subtracting or adding 180° we would get 0° or 360°, which is due North.

In the example given, we have used Magnetic Bearings, but it applies exactly in the same way with True Bearings.

USE OF BACK BEARINGS—RE-SECTION

How to find your position on a Map.

You are standing at an unknown position but can identify on the map a distant church with spire as that of Steepleton Church, and another church with tower as Towerby Church (Fig. 85).

You have a Prismatic Compass and wish to locate your exact position on the map.

Take bearings of each church. (Note that the map tells you that Mag. Var. is 11° W.).

You find bearing of Steepleton Church is 315°. True Bearing = 315°–11° = 304°.

And bearing of Towerby Church is 41°. True Bearing = 41°–11° = 30°.

Convert these into Back Bearings and you get:

Bearing from Steepleton Church to you = 304°—180° = 124°,

Bearing from Towerby Church to you = 30°+180° = 210°.

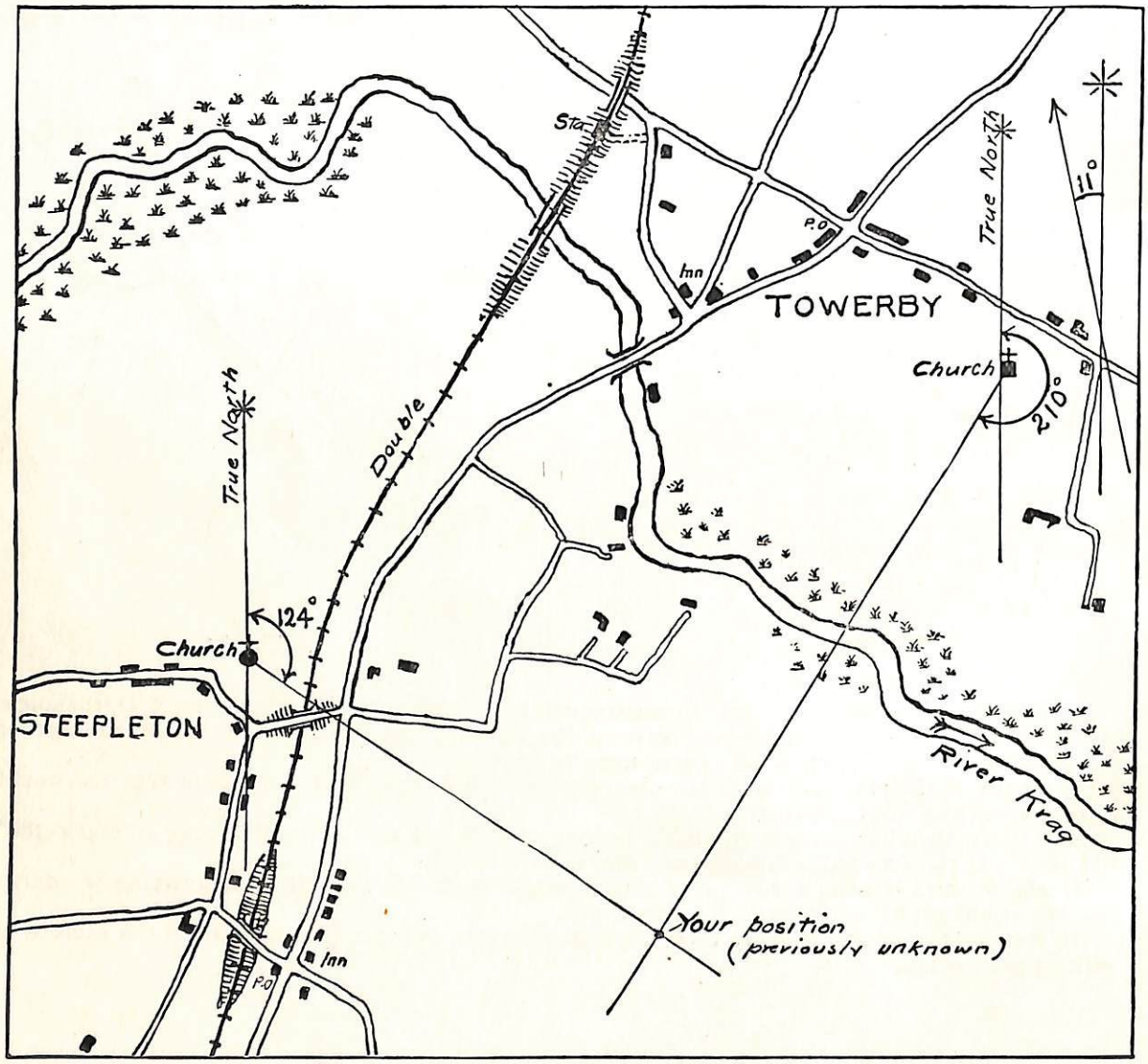


Fig. 85. Finding your Position by Re-Section

You can now, with a Protractor, draw on the map (see Fig. 85) a True Bearing from Steepleton Church of 124° and you will know that your position is somewhere on that line. Similarly you draw a True Bearing of 210° from Towerby Church and you know your position is somewhere on that line also; therefore where these two lines cross will be your position on the map.

The above example is given in such a way as to explain the Back Bearings clearly. The re-section can be done more quickly by drawing *at the distant stations* the bearings you have taken of them, and then producing them backwards. Or more quickly still, by plotting *at the distant stations* the bearings you have taken of them—with the Protractor reversed, that is, turned to left or west for Bearings under 180°, and to right or east for Bearings over 180°. This latter method is advocated in the *Manual of Map Reading and Field Sketching*.

RE-SECTION WITH A SIGHT-RULE AND PLANE-TABLE.

A Sight-rule is simply a boxwood rule or straight-edge, with metal sights at each end.

A Plane-table is merely a portable table. The board, on which the map is fixed with drawing pins, can be turned without moving the legs and clamped after "setting" the map, by placing the Box Compass along the Magnetic North line and turning the table until the Compass points to zero.

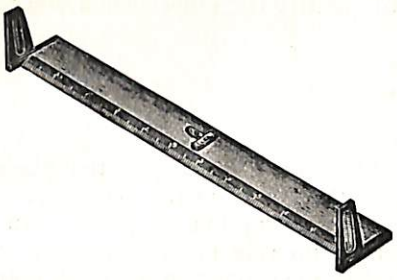


Fig. 86. Sight-rule

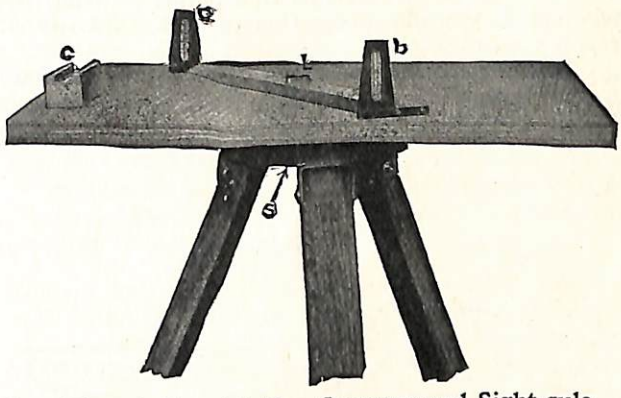


Fig. 87. Plane-table with Box Compass and Sight-rule

Example. Fig. 94, page 61, represents some actual country. Suppose your unknown position is at C and you can identify on the map the distant Windmill A and Church D. Set up the Plane-table and set the map. Place the end of the pencil at the point *a* (representing the Windmill A), and placing the edge of the Sight-rule against it, take a sight of the actual windmill along the sighting vane, and draw a line or "ray" through *a* towards you. Then your unknown position must be somewhere on this line.

Similarly take a sight of the Church through *d* (representing the Church D), and draw a ray through *d*. Then the point where this ray crosses the ray from *a* must be your position on the map.

Another ray can be drawn from the Station B which ought to cross the other rays at the same point. If they do not cross at the same point, but form a small triangle, known as the triangle of error, the true position can be determined by methods explained in the *Manual of Map Reading and Field Sketching* (page 98).

Notes: (1) This is a most accurate method, as it eliminates all question of Compass Variation.

(2) If you were standing on a known road or the line of a railway or canal, your position can be found by drawing a ray from only *one* distant object, as the point where the ray cuts the road, etc., on the map must be your position.

MARCHING BY A MAGNETIC BEARING

The Compass not only enables you to read the bearing of a given direction, but, reversedly, knowing the bearing, you can obtain the direction.

You first determine the bearing by joining the starting-point on the map to the place which you want to reach and drawing a *Magnetic* North line from the starting-point and reading the Magnetic Bearing with the Protractor.

If no Protractor is available the bearing can be obtained by first setting the map and placing the Prismatic Compass on the line AB, as shown on page 66, A being the starting-point and AB the line of march. The Magnetic Bearing can then be read opposite the lubber mark, which is a fixed mark or line on the compass body, in direct line with the sight line.

(*a*) BY DAYLIGHT AND IN OPEN COUNTRY.

Hold the Prismatic Compass up to the eye and turn the body round until the required bearing appears through the prism directly under the hair-line in the lid (vertical) when the dial is steady. The hair-line will be covering various points in the distance. From these select a prominent point, as distant as possible.

You can now march to this point, putting the compass back in its case, and when you have reached it, you obtain another distant point to march on in the same way and yet again until you reach your objective.

The farther away the point you select, the fewer number of times you use the compass, so the fewer the possible errors. It is necessary, however, to be able to identify the object when you reach it as you may possibly have to lose sight of it temporarily.

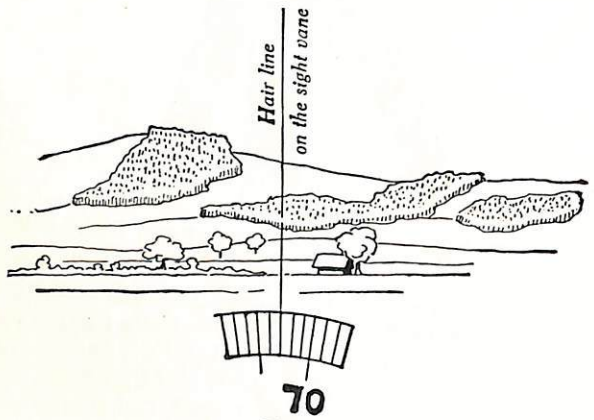


Fig. 88

Fig. 88 shows an example, the Magnetic Bearing of the line of march being 73°. The hair-line shows your line of march. In this case there is no very prominent point on it, so you select the cottage on the right, noticing that it is about a cottage-length to the right of where you want to go. When you reach the cottage, you place yourself a cottage-length to the left of it and obtain another point to march on as before.

(*b*) BY NIGHT AND THROUGH WOODS OR FOG. (1) Dry Type Prismatic Compass.

For night marching the Prismatic Compass is specially graduated round the brass ring on the outside, into 360 degrees, which are numbered from opposite the lubber line and hinge of the lid in the *reverse* direction to the hands of a watch. The reason for this will be apparent later.

Every 10th degree is numbered, but as there is little space they are numbered 3, 4, 5, etc., instead of 30, 40, 50, etc. The glass cover, on which is a radium "direction mark," is made to revolve so that the direction mark can be set to any number of degrees marked on the brass rim. Fig. 89 shows it set opposite the 7 for 70° on a dry type Prismatic Compass.

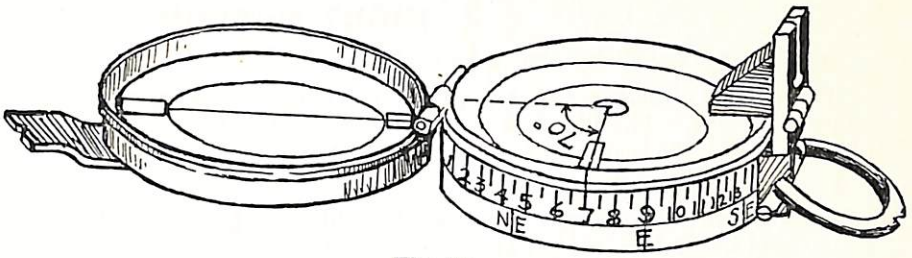


Fig. 89

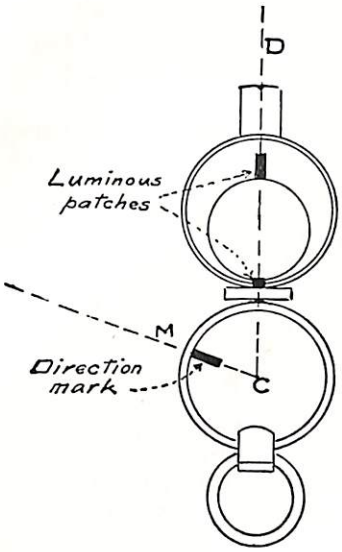


Fig. 90

All that can be seen at night are the luminous arrow on the dial, the luminous direction mark and two luminous patches inside the lid and in line with the hair-line.

The line of advance is along the hair-line or through the two luminous patches in the lid.

Now if we want to march on a Magnetic Bearing of say 70°, we first set the direction mark opposite the 70° on the brass rim, as shown in Fig. 89.

If in the dark we can then hold the compass so that the line CM (Fig. 90) from the centre to the "direction mark" points in the direction of Magnetic North, our line of advance would be along the two luminous patches, because the angle MCD is 70°. It will be noticed that we got the angle by working backwards from the line of advance to the Magnetic North, because the Magnetic Bearing is always measured from the Magnetic North line—clockwise—hence the brass rim is graduated in the reverse direction.

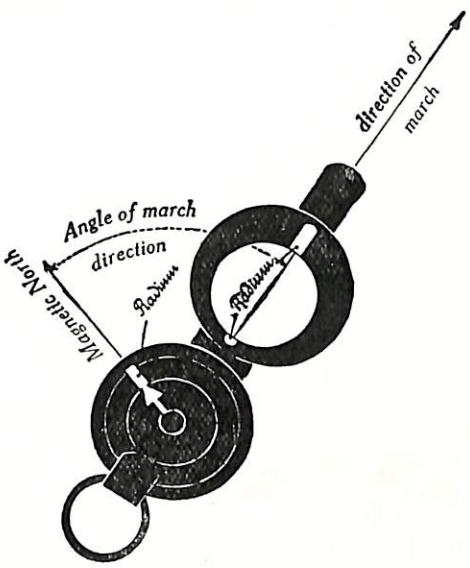


Fig. 91

Now in the dark we *can* point the direction mark towards Magnetic North by simply turning the compass round horizontally, with the dial quite free, until the luminous "direction mark" is in line with the luminous arrow on the dial (Fig. 91). The arrow will rest pointing to Magnetic North, therefore the "direction mark" is then pointing to Magnetic North and our line of march along the luminous patches must be 70°.

Put simply, then, the procedure is this :—

1. Before starting, set the direction mark opposite required bearing and *clamp* the glass cover.
2. Holding the compass with lid out flat, and with ring end of compass nearest the body, turn the body round until the luminous direction mark coincides with the luminous arrow on dial when the latter has come to rest.
3. Then the line of advance is from the centre of compass through the two luminous patches in the lid.

Note.—If the objective can be seen by daylight, its bearing can be taken beforehand and so avoid the necessity of getting it from the map.

NIGHT MARCHING.

(2) Liquid Type Prismatic Compass.

This compass (see Fig. 22, page 24) has a Transparent Rotary Scale, graduated on its top face round the rim *clock-wise*. The illuminated Index, known as Direction Mark, is attached to it directly opposite the 0° or 360°. To march by it by night, say at a bearing of 220° :—

1. Unclamp the Clamping Screw.
2. Turn the Transparent Rotary Scale until the 220° is directly over the lubber line, the position of which is shown on Fig. 92.
3. Tighten the Clamping Screw.
4. Turn round with compass until the Magnetic North Arrow comes directly under the Illuminated Index, and as long as it is kept in this position the line of march will be along the two luminous patches on the cover—opened out flat and with thumb ring close to the body. As the Index is now pointing north and is opposite 0° it is evident you will now be marching at 220°

Remember that the 220° is represented by 22, the noughts being omitted.

Maintenance of Direction. We can thus get the proper direction of march at night easily, but the maintenance of that direction is much more difficult. If stars are visible, one can be selected and marched on for 15 or 20 minutes, when another should be selected owing to their movement in the heavens.

If there are no stars or other points visible and you are alone, you must hold the compass out flat with the hand against the chest and try and keep the arrow opposite the direction mark. This is difficult with the ordinary " dry " Prismatic Compass without much practice, but much easier with the " liquid " type in which the dial is immersed in a mixture of alcohol, glycerine a nd water, and is thus much more steady.

If you have assistance you can send a man forward in the required direction until he is just discernible and halt him by a low whistle or other signal; note how much he is out of the alignment, then move up to him on the correct alignment, and go through the same process again. A luminous stick held pointing downwards at an angle of about 45° is an assistance to the guide. By using an electric torch the guide can go further ahead.

Another man should be detailed to count the number of paces and record the total distance covered.

TO IDENTIFY ON THE MAP A VISIBLE DISTANT OBJECT

It is assumed the observer's position has been identified.

(*a*) *When you have a Protractor.*

1. Take a bearing of the distant object.
2. Plot this bearing on the map by using the Protractor.
3. Then this line will pass through the distant object as shown on the map.
4. Estimate its distance from you and the object can be identified.

(*b*) *Without a Protractor.*

Your position is near the angle of the wood (Fig. 92) and you want to fix the position on the map of a distant church steeple.

1. Take a Compass Bearing of the steeple (say 61°).
2. Set the map (by one of the methods on following pages).
3. Lay the compass on the map with the notch on the ring exactly on the spot you identify as your position.
4. Holding the map steady, turn the compass round, with the ring notch as centre, until the lubber mark comes opposite the degrees of the bearing (61°) on the inner circle of the dial.

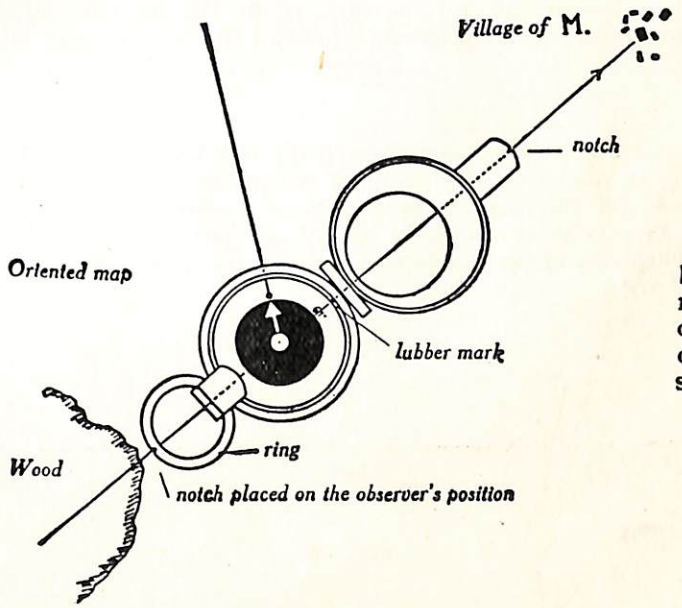


Fig. 92

Note.—The "lubber mark" is a fixed mark or line on the compass *body*, in direct line with the sighting line.

5. Make a pencil dot marking the position of the notch at the other end of the compass.
6. Remove the compass and draw a pencil line from your position through this dot. Then this line obviously represents the bearing of the steeple which must be somewhere on it.

Looking at the map, you notice that the line passes through the village of M, and the distance corresponding, you know that the steeple must be the steeple of the church in the village of M.

SETTING THE MAP—VARIOUS METHODS

(*a*) WITHOUT A COMPASS

1. **When you can identify your position on the map and also that of some distant object,** say the church D (Fig. 94).

Lay out the map horizontally on a table or the ground.

Suppose you are standing at the spot C, then the point *c* on the map is identical with the point on which you are standing.

Now you identify the church *d* on the map with the actual church D in the distance.

On the map join *cd* with a pencil line.

Rotate the map until the direction *cd* corresponds with the direction CD to the actual church.

The map is now set.

This is one of the best methods, and if the church is sighted carefully on a table and preferably with a Sighting Rule (which is a straight edge and is laid along the line *cd*, and a sight taken on the distant object through a hair-line) the most accurate, as it eliminates the question of Magnetic Variation and all sources of error in the compass.

Directions to other distant objects, such as the Windmill A and the railway station at B, will be found to coincide with the directions of the same objects on the map from *c*.

2. **When exact position is unknown.** Place yourself directly between two prominent objects which you can identify on the map, say windmill A and church D (Fig. 93), and then so arrange the map that *ad* on the map is directly in line with and coincides with the imaginary line AD. The map is then obviously set. It is sometimes difficult to do. If you place yourself in prolongation of the line joining the two prominent objects you could set the map similarly.

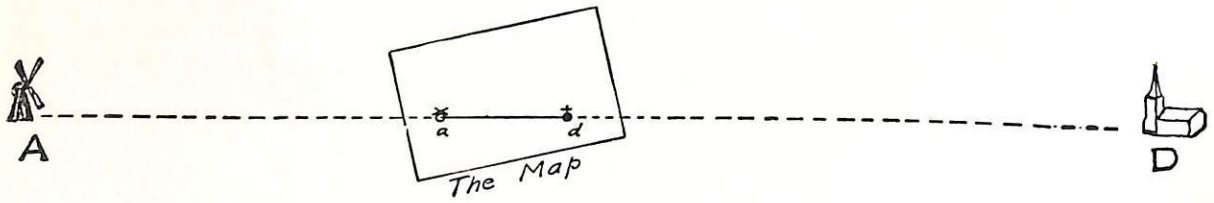


Fig. 93

3. **When near a straight road or railway, etc.** Approximate. Place or hold the map so that the corresponding road or railway, etc., on the map is parallel.

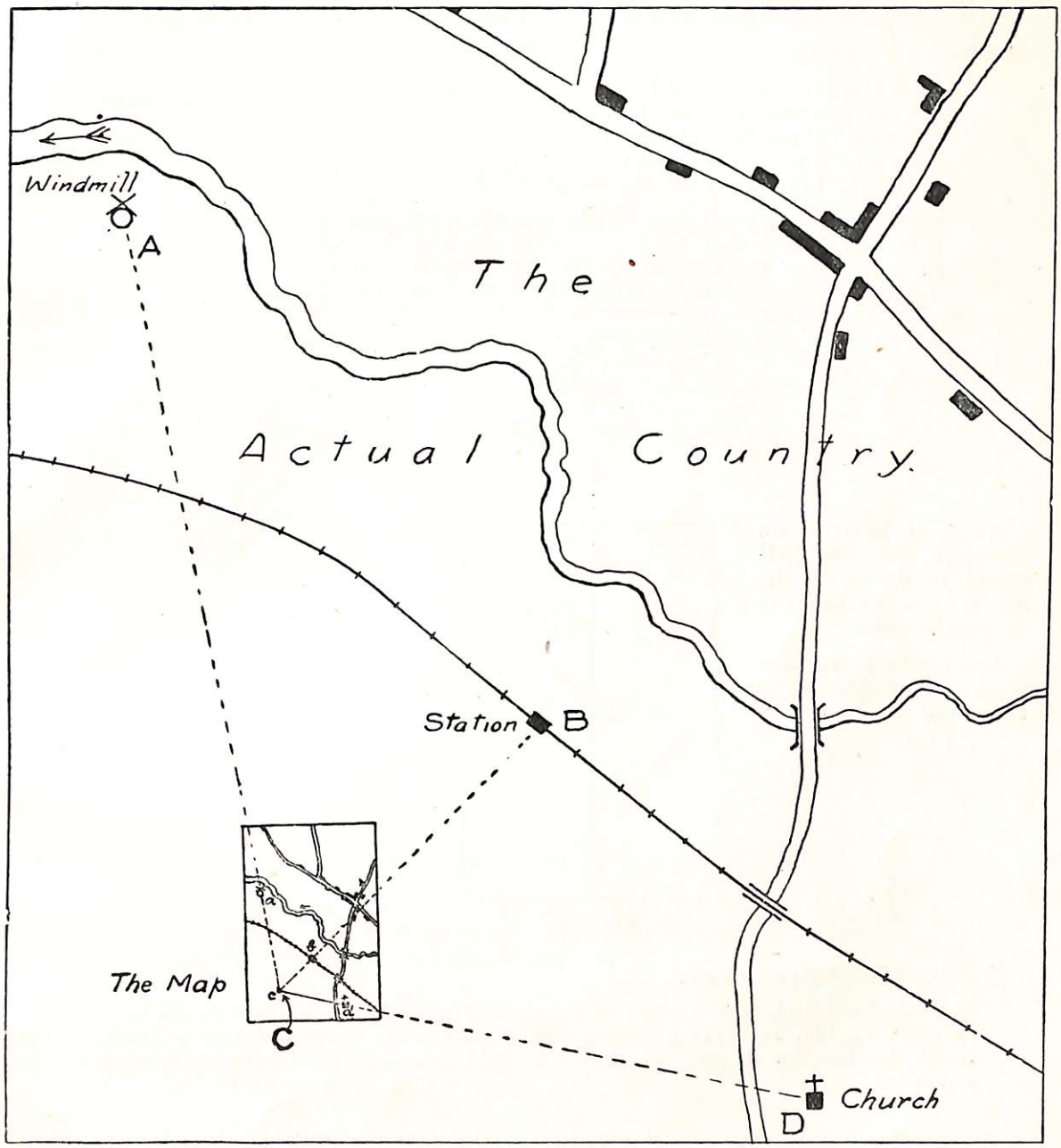


Fig. 94. Setting the Map

4. By the position of the Sun, i.e. by placing the map so that the North and South line thereon corresponds with the real North and South direction, which we can find as follows :—

(*a*) *With a Protractor.*

SN is the True South and North line on the map.
The sun is always due South at noon.
It moves 15° per hour clockwise.
Time now 2.30, i.e. $2\frac{1}{2}$ hours since noon.
∴ the sun has moved $15° \times 2\frac{1}{2} = 37\frac{1}{2}°$.

Set off from any point A in SN the line AB at an angle of $37\frac{1}{2}°$ with the Protractor. Place the map so that AB points to the sun and the map will be set Fig 95).
(If a pin were stuck in the paper vertically at B and the map turned so that its shadow fell along BA then AB would be in a direct line with the sun.)

Note.—If the time were forenoon the line AB would be drawn to the *left* of SN, as the sun moves clockwise.

In summer time, *noon* must be reckoned as 1 o'clock.

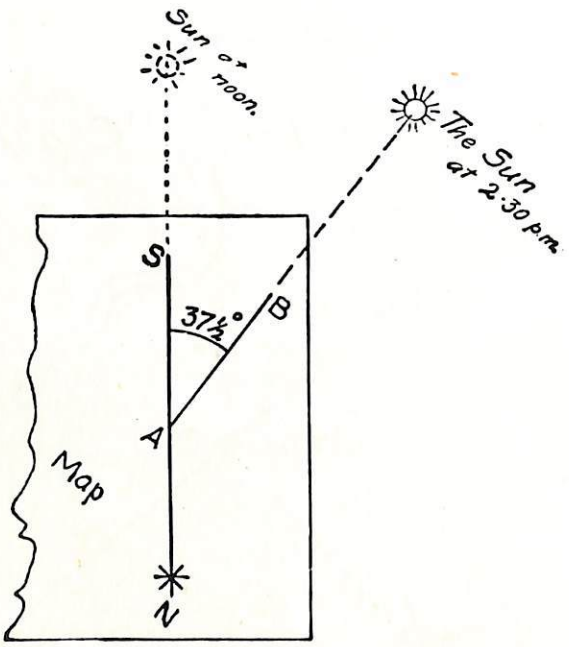


Fig. 95

(*b*) *With a Watch* (approximate).

Place the watch on the map and ascertain from it the direction of North as explained on page 29, Fig. 25. Then, holding the watch steady, move the map so that the true North line thereon is pointing in the same direction as you have obtained from the watch.

(*b*) WITH A COMPASS

1. With a Card Compass (e.g. Prismatic Compass).

(*a*) *From the True North Line on the map.*

1. Open out the Compass flat and place it with its centre line as shown by the notches at each end, over the True North line (produced if necessary) or true meridian (Fig. 96).

2. Turn the map round with the compass still lying along the North line, until the lubber mark (which is on the centre line of the compass) is opposite the number of degrees (on the inner circle of the dial) showing the Compass Variation. The map is now set.

In the diagram, the Compass Variation is 11° W. and the map and compass have been moved round until the lubber mark is opposite 11° on the inner circle of degrees on the dial.

Note.—To read the number of degrees accurately against the lubber mark, hold the body of compass steady and nearly close the lid, and by looking through the window the hair-line can be used as a guide.

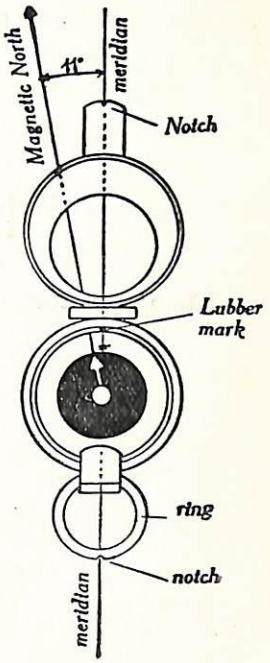


Fig. 96

(*b*) *From the Magnetic North Line on the map.*

Place the compass on the map in a similar manner as in Fig. 97, but along the *Magnetic* North Line on the map and rotate the map (and compass on it) until the Magnetic North line on the map (produced if necessary) is exactly under the zero on the inner dial (the north end of the magnet). The map is now set.

The Magnetic North line should be drawn for the same year as the map is being used, i.e. allowing for the decrease or increase of Magnetic Variation as explained on page 47. Any error in the compass should be allowed for.

Note.—The Trough or Box Compass described on page 24 can be equally well used for this, by placing the edge of the compass along the Magnetic North line.

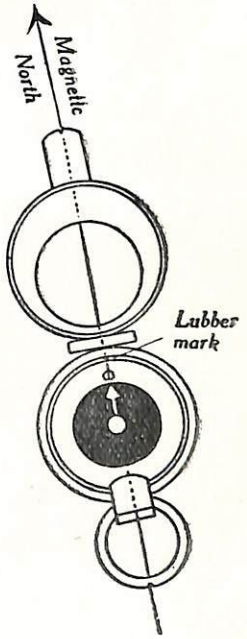


Fig. 97

2. **With an Ordinary Compass** (with a graduated case or base).

From the True North Line on the map.
Suppose Compass Variation is 15° W.

1. Place the compass on the map so that the N. and S. of the case (0°–180°) coincides with the N. and S. line or meridian on the map (Fig. 98).
2. Without disturbing the needle rotate the map till the North of the case (0° or 360°) is 15° East of the needle (Fig. 99). (The degrees are counted backwards from 360°.)

The map is then set.

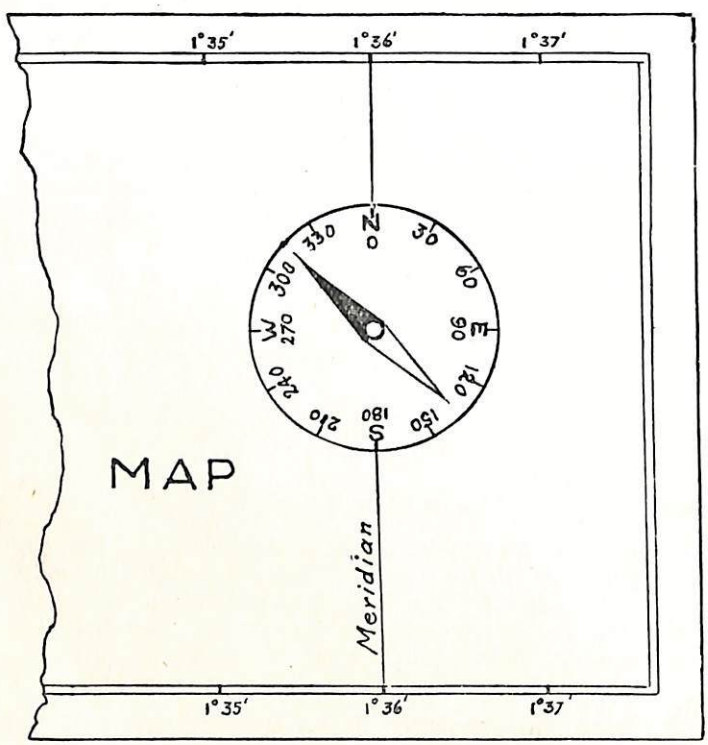


Fig. 98. Setting the Map with an Ordinary Compass. First Position

THE MAP SET WITH AN ORDINARY COMPASS

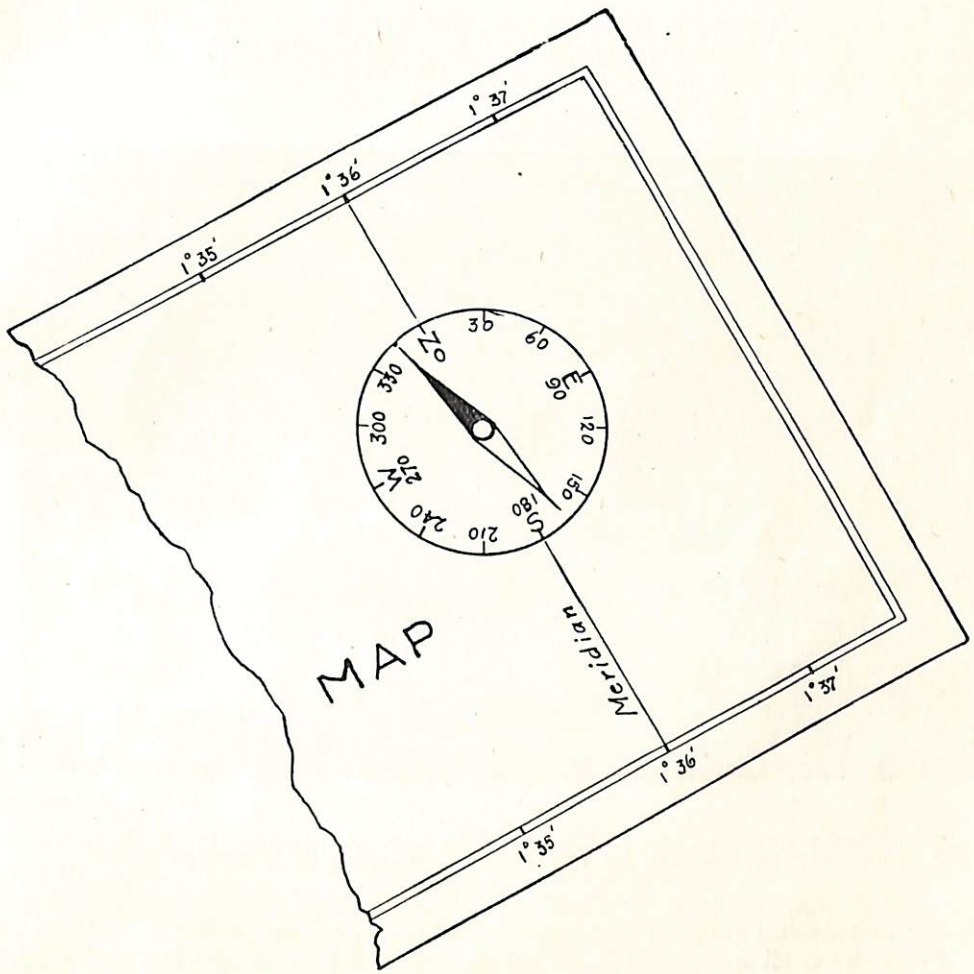


Fig. 99. Position after Rotating the Map to allow for Magnetic Variation (in this case 15°)

3. When your position and a distant object can be identified on the map.

1. Take the bearing with your compass of the distant object B from your position A (Fig. 100). Say it is 73°.
2. On the map draw a pencil line from your position A to position of the distant object B.
3. Lay the compass on the map with the ring towards A, so that the centre line of the compass is exactly over the line drawn (AB) by means of the notches EE.
4. Turn the map round (together with the compass) until the degree of the bearing (73°) on the inner circle of the dial is opposite the lubber mark inside the box under the hinge (not shown in Fig. 100, but shown in Fig. 92). The map is now set.

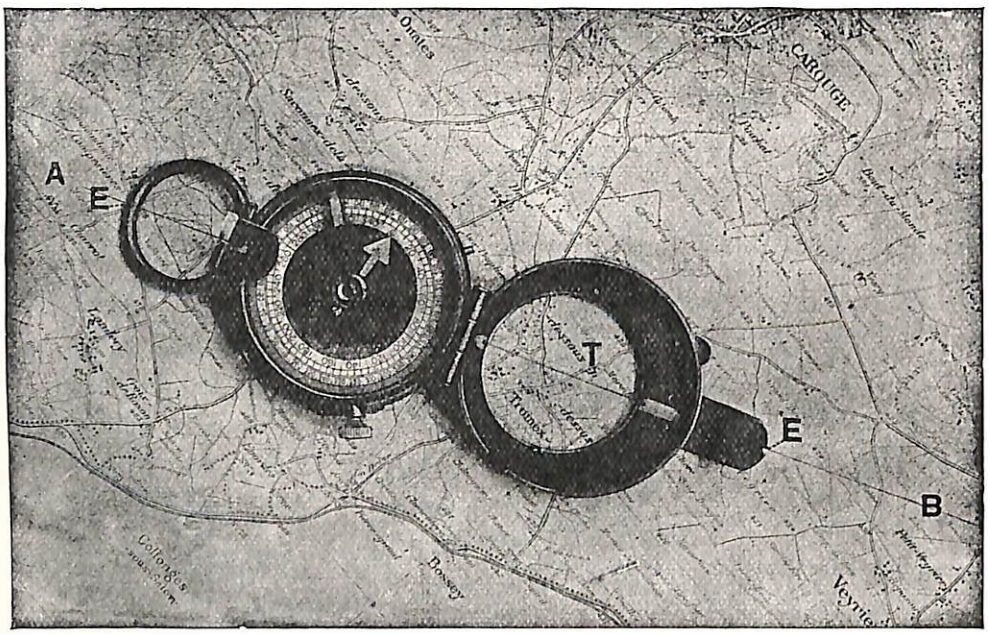


Fig. 100. Setting the Map by first taking a bearing of a distant object

This method eliminates all question of Magnetic Variation or Compass Error, and can be done if there is no North line at all on the map. Moreover, once the Bearing has been taken, the map can be set under cover or in a trench.

PART III

DISTANCE

Every map bears a certain definite proportion to the country which it represents, and this proportion is known as the Scale of the Map. In order to measure any distance on the map you must first know what is the proportion between the map and the ground it represents.

SCALES

A Scale denotes the proportion which a distance between two points on a map bears to the horizontal distance between the same two points on the actual ground.

How denoted. There are three ways of giving the scale on the map.

1. **By Statement,** e.g. " 4 inches to the mile " (4″=1 mile), or this might be stated " $\frac{1}{4}$ mile to the inch."

   This means that 4 inches on the map represent 1 mile on the ground—or $\frac{1}{4}$ mile on the ground is represented by 1 inch on the map.

   The advantage of this method is that we can judge fairly accurately in inches, and thus can, at a glance, tell a distance on a map approximately in miles.

2. **By a Representative Fraction,** e.g. $\frac{1}{80,000}$.

   This means that 1 unit on the map represents 80,000 of the *same* units on the ground.

   Thus 1 inch on the map represents 80,000 INCHES on the ground.

   As 80,000 *inches*$=\frac{80,000}{63,360}$ miles$=1{\cdot}261$ miles, we can now say that

   1 inch represents 1·261 miles.

   This Representative Fraction (R.F.) is given on all foreign maps of the present day, and should be given on all military and other maps of our own.

   From it we can work out the scale in inches to the mile, or construct a Plain Scale, if necessary, as below.

3. **By a Straight Line divided and marked** to show what these divisions actually represent on the ground.

Such a scale is known as a **Plain Scale** for the purpose of distinction, e.g —

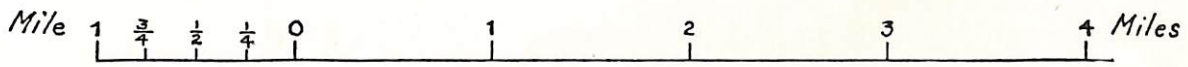


Fig. 101. A Plain Scale

All three of these methods give the *same* information, namely, the proportion of the map to the actual ground.

It is advisable to get accustomed to looking at scales from the point of view of the R.F. (Representative Fraction), i.e. to have a good idea of the size of the scale when you know the R.F., as this shows the actual proportion in figures.

The advantage of having the R.F. on a map can be understood by this case. If an antiquated map were dug up at Pompeii and had the R.F. on it, this information would enable you to calculate any and every distance represented on the map. If, on the other hand, it gave the scale by statement in some obsolete unit of measurement and in a language which you did not understand, it would convey no useful knowledge to you at all.

It is thus very necessary to be able to convert the R.F. into a statement referring to our measurement of inches and vice versa. The way to do this will be explained.

The Plain Scale is also drawn on all maps. The advantage of this, of course, is that any distance you require to know can be taken from the map on a pair of dividers, or by ticking off the distance on a strip of paper and by applying this distance to the Plain Scale, the actual distance on the ground represented can be read off without having to calculate it. In making a map the Plain Scale is the first thing to draw on the paper so that you can work from it, unless you have the scale on the Protractor. It must, however, be drawn on the map, anyway.

It is thus necessary to be able to construct Plain Scales from the R.F. This will also be explained.

A Large Scale Map is a map on which a distance on the ground is represented by a comparatively large measurement. One of the largest scale usually used on maps is 6 inches to the mile $\left(\text{R.F. } \frac{1}{10{,}560}\right)$, which means that a mile on the ground is represented by 6 inches on the sketch. This enables minute details to be given—every road and village, etc. with names, and even individual houses and their shape can be shown.

A Small Scale Map is one on which a distance on the ground is represented by a small measurement. Such a map would show a large area but there would only be room to show large towns, small details being impossible.

A scale of 6 miles to the inch $\left(\text{R.F.} = \frac{1}{380{,}160}\right)$ would be used for strategical purposes, or to show the disposition of whole armies, etc.

Note.—When making a sketch or a map, the longest distance required to be represented is known, and if a certain scale is required, the size of paper wanted for the map can be found by the Method of Unity, for an explanation of which see page 70. Similarly if the size of paper is first decided upon, a suitable size scale can be found.

Example.—Longest distance 10 miles. Length of paper 24″ less 4″ for margin = 20″.

∴ 20″ will represent about 10 miles.

1″ ,, ,, $\frac{10}{20}$ miles = ½ mile.

A suitable scale would be 2″ to the mile.

Representative Fraction Scales

The following will give the reader a good idea of Scales expressed by the R.F. :—

$\frac{1}{10{,}000}$ suitable for sale of estates, giving acreage of fields and shapes of houses.

$\frac{1}{20{,}000}$ showing houses, fields, fences, etc.

$\frac{1}{50{,}000}$ for a walk in country, showing footpaths clearly.

$\frac{1}{100{,}000}$ for bicycling or a walking tour, showing all roads.

$\frac{1}{200{,}000}$ for motoring maps—main roads chiefly.

$\frac{1}{500{,}000}$ for maps of large districts.

The following is a list of the Scales mostly used on military maps :—

	R.F.	Equivalent in Miles and Inches		Use.
Large Scale Maps.	1/10,000	1″=·15 miles *or*	6·33″ to 1 mile	To show towns, villages, etc., or position for a camp, or the area for billeting troops.
	1/10,560	1″=·16 miles *or*	6″ to 1 mile	
	1/15,840	1″=¼ mile *or*	4″ to 1 mile	
	1/20,000	1″=·31 miles *or*	3·17″ to 1 mile	Military Gridded Map.
	1/25,000	1″=·39 miles *or*	2·53″ to 1 mile	Roads, rivers, etc.
	1/25,344	1″=·4 miles *or*	2½″ to 1 mile	Reconnaissance sketch.
	1/31,680	1″=½ mile *or*	2″ to 1 mile	To explain a plan of attack for modern fighting as opposed to manœuvring.
	1/40,000	1″=·63 miles *or*	1·58″ to 1 mile	To show lines of advance.
	1/50,000	1″=·79 miles *or*	1·26″ to 1 mile	Defensive Positions. Outpost Positions.
Small Scale Maps.	1/63,360	1″=1 mile *or*	1″ to 1 mile	
	1/80,000	1″=1·26 miles *or*	·79″ to 1 mile	Tactical Map of France.
	1/100,000	1″=1·58 miles *or*	·63″ to 1 mile	Tactical Map of Belgium and Germany.
	1/126,720	1″=2 miles *or*	½″ to 1 mile	
	1/250,000	1″=3·95 miles *or*	·253″ to 1 mile	General Maps of France, also of Belgium and Germany, with 2″ squares.
	1/380,160	1″=6 miles *or*	·16″ to 1 mile	Large Tracts of Country. Strategical Map of Belgium and N.E. France in Sections.

It will be noticed that British large Scale maps are "Inches to the Mile," and small Scale maps are "Miles to the Inch."

Note.—It is the common practice nowadays to write a fraction thus :—1/25,000 instead of the old form $\frac{1}{25,000}$. The latter form is used in this book, as it is better for instructional purposes.

R.F. 1/1,000,000 commonly written 1/M=approximately 16 miles to 1 inch. This is useful to remember, as by comparison 1/250,000=about 4 miles to 1 inch. Similarly 1/2M=about 32 miles to 1 inch.

Maps of 1/500,000 to 1/5M are used for Countries and 1/5M to 1/50M for Continents.

CONVERTING SCALES

The best way to do this is by the Method of Unity. As many people seem to be somewhat hazy on this all-important Method of Unity, we think it advisable to occupy a small place in order to try and thoroughly explain it.

Suppose you have bought 45 oranges for 12s.

(*a*) What would 175 oranges cost you?
(*b*) How many oranges would you get for £1?

(*a*) Begin with a statement of the fact you know, *putting the cost last*, as this is what you want to know.

45 oranges cost 12 shillings.

Now find the cost of 1 orange.

It is evident that $\frac{1}{2}$ the number will cost $\frac{1}{2}$ the price, or $\frac{1}{4}$ the number costs $\frac{1}{4}$ the price, or

$\frac{1}{45}$th the number of oranges will cost $\frac{1}{45}$th the price.

$\therefore$ $\frac{1}{45}$th of 45 oranges will cost $\frac{1}{45}$th of 12s.

Now $\frac{1}{45}$th of 45 oranges is 1. Thus $\frac{45}{45}=1$.

$\therefore$ 1 orange will cost $\frac{12}{45}$ shillings.

Now any multiple of 1 orange will cost the same multiple of $\frac{12}{45}$ shillings.

Thus $(1\times 2)=2$ oranges will cost $\left(\frac{12}{45}\times 2\right)$ shillings.

or $(1\times 4)=4$,, ,, $\left(\frac{12}{45}\times 4\right)$ shillings.

or $(1\times 175)=175$,, ,, $\left(\frac{12}{45}\times 175\right)$ shillings.

This is what we want to find.

The above is to show the reasoning. The following is the way in which you work it out:

If 45 oranges cost 12 shillings.

Then 1 orange costs $\frac{12}{45}$,,

$\therefore$ 175 oranges cost $\left(\frac{12}{45}\times 175\right)$ shillings $=46$s. 8d.

(*b*) Take the second case. You have bought 45 oranges for 12s., how many would you get for £1?

In this case you start again with the statement of the fact you know, but as the answer you want is in oranges, you state the fact so that the oranges come *last*, and proceed in the same way, thus:—

For 12 shillings I get 45 oranges.

$\therefore$ for $\frac{12}{12}$ shillings ,, $\frac{45}{12}$ oranges.

i.e. for 1 shilling ,, $\frac{45}{12}$ oranges.

Then for (1×20) shillings ,, $\left(\frac{45}{12}\times 20\right)$ oranges.

i.e. for 20 shillings ,, $\left(\frac{45}{12}\times 20\right)$ oranges $=75$ oranges.

The above is to explain the reasoning, the simple form in which you work it out is thus :—

For 12 shillings I get 45 oranges.

$\therefore$ for 1 shilling ,, $\frac{45}{12}$ oranges,

$\therefore$ for 20 shillings ,, $\left(\frac{45}{12}\times 20\right)$ oranges $=75$ oranges.

An example with Scales.

With a map of 2 inches to 1 mile, what distance on the map would represent 5,000 yards ?

Now here you have the fact that 2 inches on the map represents 1 mile of country. As you want to know the distance on the *map* start with the statement, putting this *last*, thus :—

1 mile is represented by 2 ins.

Now as we are asked a question about *yards*, convert the mile into yards :

1760 yards is represented by 2 ins.

$\therefore$ 1 yard ,, ,, $\frac{2}{1760}$ ins.

$\therefore$ 5000 yards ,, ,, $\left(\frac{2}{1760}\times 5000\right)$ ins. $=\frac{125}{22}$ ins. $=5{\cdot}68$ ins.

EXAMPLES OF CONVERTING SCALES

These figures should be remembered. 1 mile = 1760 yards. (Denoted thus $1760^{\times}$).
1 mile = 5280 feet. (Denoted thus $5280'$).
1 mile = 63,360 in. (Denoted thus $63{,}360''$).

The following examples will speak for themselves.

1. Given a scale of 4″ to the mile, what is the Representative Fraction (R.F.) ?

Find out how many inches of the ground is represented by 1″ on map.

4 inches represent 63,360 inches (1 mile).

$\therefore$ 1 inch ,, $\frac{63{,}360}{4}$ ins. $=15{,}840$ ins.

$\therefore$ R.F. is $\frac{1}{15{,}840}$

2. What is the R.F. if the Scale is 4 miles to the inch ?

1 inch represents 4 miles.

$\therefore$ 1 inch ,, $(4\times 63{,}360)$ inches $=253{,}440$ inches.

$\therefore$ R.F. is $\frac{1}{253{,}440}$

3. If the R.F. is $\frac{1}{100{,}000}$ what is the Scale in miles to the inch ?

1 unit represents 100,000 units on the ground.

Thus 1 inch ,, 100,000 inches $=\frac{100{,}000}{63{,}360}$ miles $=1{\cdot}58$ miles.

$\therefore$ Scale is $1{\cdot}58$ miles to the inch.

4. **A French Map has a Scale 1 centimetre = 1 kilometre. What is the Scale in inches to the mile?**
Here we must be aware that 1 kilometre = 1000 metres = 100,000 centimetres.
Since 1 centimetre represents 1 kilometre, or 100,000 centimetre,

Then R.F. is $\frac{1}{100,000}$.

$\therefore$ 100,000 inches would be represented by 1 inch.

1 inch " " $\frac{1}{100,000}$ inch.

$\therefore$ 63,360" (1 mile) " " $\frac{63,360}{100,000}$ inches = ·63 ins.

Thus the Scale is ·63 inches to the mile.

PLAIN SCALES

Let us take the simple case of a Scale 1" = 1 Mile. A straight line is drawn and inches are measured off along it—say with a pair of dividers. Each of these divisions will then represent 1 mile. The first division is kept apart for subdivisions, called secondary divisions—in the case of miles it would be divided into 4 equal parts to give $\frac{1}{4}$ miles.

The other divisions (called primary divisions) are numbered, beginning at the point B, Fig. 102. This is marked O, and the miles are numbered to the right.

The secondary divisions are numbered to the *left*, and in the case of miles would be numbered $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ and 1.

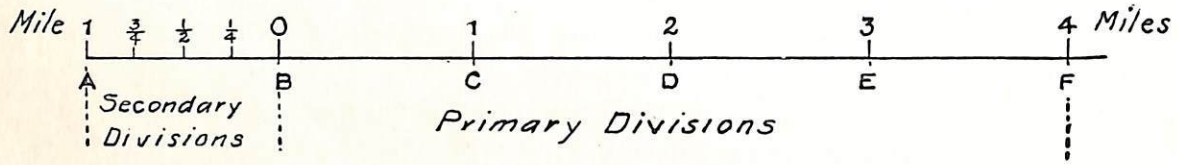


Fig. 102

Reading off a distance on the Scale, always start from zero (0).

Fig. 103 shows a Scale of $\frac{1}{2}$ inch to the mile. Suppose you have measured a distance on the map with the dividers and want to find what it represents.

1. Place one point in the paper at zero, and the other on the line to the right. You find it is 3 miles and a part of a mile, so you

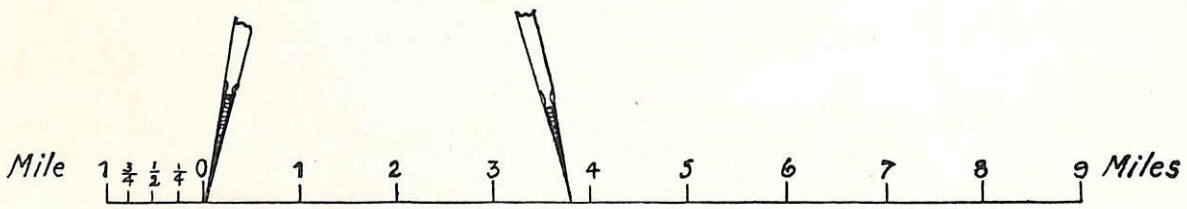


Fig. 103

2. Move the dividers so that the right hand point is on the 3 division and you find the left point comes on the secondary division marked $\frac{3}{4}$ (Fig. 104).
3. The length on your dividers is evidently $3+\frac{3}{4}=3\frac{3}{4}$ miles. This explains why the secondary divisions should be numbered from *right to left.*

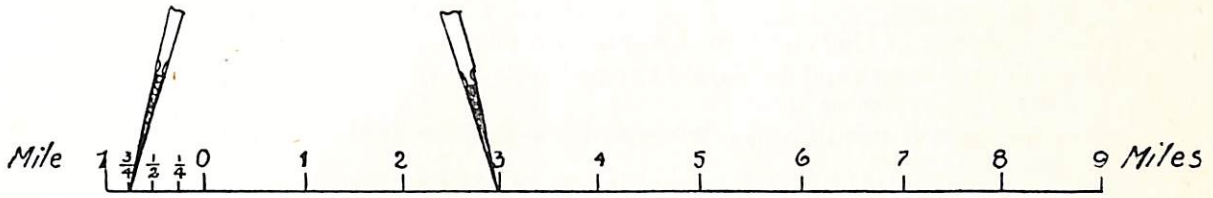


Fig. 104

(A distance could equally well be read when ticked off on a strip of paper.)

Taking a Measurement from the Scale.

Similarly, suppose you want to take off a measurement of $7\frac{1}{4}$ miles, you obviously put the right-hand point of the dividers on the 7 and open out the dividers to the left, so that the left point comes on the $\frac{1}{4}$ and you get $7+\frac{1}{4}=7\frac{1}{4}$ miles.

CONSTRUCTING PLAIN SCALES

You sometimes have to make your own Scale; for instance, you have a foreign map with the R.F. on it, but find the plain scale is for kilometres, which is of no use to you.

Primaries should be chosen to show *miles* or *kilometres* in units, 10's or 100's or *yards* in 1000's or 500's—according to the unit of measure shown and the size of the scale.

Secondaries should show $\frac{1}{4}$ *miles*, $\frac{1}{20}$ kilometres or 100 yds.

Thus:—	*Scale.*	*Primaries.*	*Secondaries.*
	Miles.	Miles.	$\frac{1}{4}$ miles.
	Yards.	1000 yds. (small scales up to 2″ to 1 mile).	100 yds.
		500 yds. (larger scales).	

Military *sketches* can rarely be of sufficient accuracy to make it necessary to show small Secondaries. These are, however, shown on the Protractor, which may be used to measure distance on Military *maps*.

A Scale should be about 6 inches long.

The Method. (Scales should be worked out to two decimal points.)

First draw a straight line over 6 ins. long at the bottom of map.

Some Scales will have Primary Divisions of over an inch or 2 inches. In this case, it is quickest to find, by the Method of Unity, the *exact* length the Primary Divisions (representing say 1 mile or 1000 yards, etc.) will measure. Then take this distance on the dividers and step it out on the line. Then to subdivide the first division into suitable Secondary Divisions and number them as explained.

Other Scales, however, will have quite small Primary Divisions, as will be seen in some examples that follow. In this case in stepping it out a large number of times, if there is the slightest error in taking the measurement on the dividers (even 100th of an inch), this error being repeated many times, the total length will be quite appreciably incorrect. It is best, in such a case, to obtain a measurement about the total length of the scale, i.e. about 6 ins. long and subdivide it. The length will have to represent a *round* figure which is a multiple of the distance to be represented by a primary division.

The way to do this is as follows:—

1. Find by Method of Unity what distance 6 ins. on the map will represent. This may be an odd amount, say 13,333 yards. Now if our Primary Divisions are thousands of yards, select a round number rather less than this, which is a multiple of 1000, say 12,000 yards, and then
2. Find by Method of Unity the exact length of a line to represent 12,000".
3. Draw a line this length and divide into 12 equal parts (by method shown in Appendix, page 86), and each division will represent 1000".
4. Subdivide the left hand division into suitable secondary divisions and number them as explained.

EXAMPLE 1. Given the R.F. $=\frac{1}{25,000}$, construct a Scale to show thousands of yards (primary) and hundreds of yards (secondary). Find what distance on the map will represent 1000 yards.

25,000 yards is represented by 1 yard

$\therefore$ 25,000 yards " " 36 inches

$\therefore$ 1 yard " " $\frac{36}{25,000}$ inches

$\therefore$ 1000 yards " " $\left(\frac{36}{25,000}\times 1000\right)$ inches $=\frac{36}{25}=1{\cdot}44$ inches.

Draw a straight line, take the measurement 1·44 inches on the dividers (this can be obtained exactly from the diagonal scale on the protractor as explained later) and step it off along the line. Each of these divisions will represent 1000 yards. Divide the first one on the left into 10 equal parts and each division (secondary) will represent 100 yards. (To divide a line into equal parts, see page 86.) Number the divisions as shown in Fig. 105 and write the words YARDS as shown.

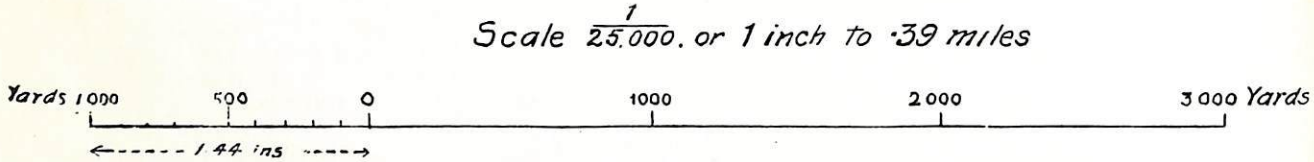


Fig. 105

Note.—Military Maps. Fig. 105 shows the exact method of showing the scale as laid down in the *Manual of Map Reading and Field Sketching*. The length 1·44 ins. of the first Primary division is only put in for explanation.

EXAMPLE 2. R.F. $=\frac{1}{100,000}$. Construct a Scale to show miles.

100,000 inches are represented by 1 inch

$\therefore$ 1 inch " " $\frac{1}{100,000}$ inches

$\therefore$ 1 mile (63,360") " " $\frac{1\times 63,360}{100,000}$ inches $=\cdot 634$ inches

Here we can at once see that 9 miles would be represented by 5·706 ins.– a suitable length.

Draw a line and measure off a distance of 5·7 inches (from the diagonal scale to get decimals). Divide the line into 9 equal parts, then each division must represent 1 mile (Fig. 106).

Divide the first division into 4 equal parts and each will represent ¼ miles.

Number the divisions as shown and write MILES or MILE at each end.

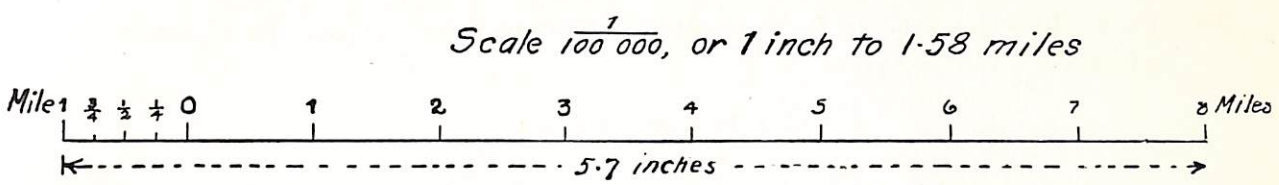


Fig. 106

Example 3. R.F. $=\frac{1}{80,000}$. Construct a Scale to show 1000 yards and 100 yards.

80,000× is represented by 1× = 36 inches.

1× " " $\frac{36}{80,000}$ inches

∴ 1000× " " $\left(\frac{36}{80,000}\times 1000\right)$ inches $=\frac{36}{80}$ inches.

This is too small to step off accurately, so find what 6″ will represent.

1 foot represents 80,000 feet $=\frac{80,000}{3}$ yards

∴ ½ foot (6″) " $\left(\frac{80,000}{3}\times\frac{1}{2}\right)$ yards $=13,333\frac{1}{3}$ yards.

Now select a round number, say 10,000, and find what length in inches will represent it—we know it will be rather less than 6″.

80,000× is represented by 1× = 36 ins.

∴ 1× " " $\frac{36}{80,000}$ ins.

∴ 10,000× " " $\left(\frac{36}{80,000}\times 10,000\right)''=\frac{36''}{8}=4{\cdot}5$ ins.

Draw a line $4\frac{1}{2}$ ins. long, divide it into 10 equal parts, and each division represents 1000×. Subdivide the first one into 10 equal parts and each division = 100×. Number the divisions as explained and write YARDS above the line.

Example 4. Construct a Scale of 4 inches to 1 mile to show 500 yards and 100 yards.

As 4 ins will represent 1760 yards (1 mile),

Then 6 ins would represent half as much again, or 2640 yards.

Now we must have a multiple of 500, as each division is to represent 500 yards. So we select 2500 yards.

As 1760 yards is represented by 4 ins.

1 yard " " $\frac{4}{1760}$ ins.

∴ 2500 yards " " $\left(\frac{4}{1760}\times 2500\right)$ ins. $=5{\cdot}68$ ins.

Draw a line 5·68 ins. long and divide it into 5 equal parts and each will represent 500 yards. Subdivide the first division into 5 equal parts and then each division will represent 100 yards.

Example 5. Having a Scale of Yards construct a Scale of Paces. Suppose your paces to be 30 inches $=\frac{30}{36}$ yards $=\frac{5}{6}$ yards.

$\frac{5}{6}$ yard is the length of 1 pace.

$\therefore$ 1 yard ,, ,, $\frac{1}{\frac{5}{6}}$ paces $=\frac{6}{5}$ paces.

$\therefore$ 500 yards ,, ,, $\left(\frac{6}{5}\times 500\right)$ paces $=600$ paces.

On the under side of your Yard Scale mark the 500$^{\times}$ division. Then from zero to this point will represent 600 paces.

Step off this distance from zero to the right and number 600, 1200, 1800, etc., paces and make 1 division to the left of zero and subdivide into 6 equal parts, and these secondary divisions represent 100 paces.

Such Scales showing two units together are called Comparative Scales. See page 79, where will be found Scales showing Miles on top and Yards below.

Time Scales are sometimes useful, in order to read off directly from them the time it will take to march a certain distance, and also that the distance travelled may be ascertained from time taken.

Example 6. To Construct a Time Scale for a Column of Troops marching at 3 miles an hour. Scale of map 2 miles to 1 inch.

Since 1″ represents 2 miles, then 6″ represents 12 miles.

As the rate of march is 3 miles an hour, 12 miles takes 4 hours.

$\therefore$ 6 inches will represent the time taken to march 4 hours. Draw a line 6 ins. long and divide into 4 equal parts and each will represent 1 hour's march. Subdivide the left division into 12 equal parts, then each will show $\frac{1}{12}$ hours march $=\frac{60}{12}$ minutes $=5$ minutes.

Using Scales on the Protractor. The above examples are given fully to explain how *any* Scale can be worked out by the Method of Unity. In practice, one can use one of the Scales on the Protractor when suitable, but it must be copied carefully on to the sketch.

In practice, moreover, most Scales can be constructed from those on the Protractor; e.g. a Scale 6″ to 1 mile can be easily constructed from the 2″ to 1 mile on the Protractor. The distance denoting 300 yards on the Scale would represent 100 yards at a Scale of 6″ to 1 mile. Therefore place the Protractor along a line on the paper and tick off every 300 yards up to say 1500. Leaving the left for secondary divisions, number the divisions thus made 0, 100, 200, 300, etc., instead of 0, 300, 600, 900, etc.

Thus from the 2″=1 mile, 3″, 4″, 6″, 8″, and 12″ to the Mile Scales can be constructed.

From the $\frac{1}{20,000}$ Scale can be similarly constructed Scales of $\frac{1}{80,000}$, $\frac{1}{40,000}$, and $\frac{1}{10,000}$. Also from the $\frac{1}{100,000}$ Scale you can easily construct those of $\frac{1}{50,000}$ and $\frac{1}{25,000}$.

The following is a general rule for using the Protractor to derive other Scales in terms of British units, supposing n ins. to the mile is the required Scale. Regarding the 2 ins.=1 mile as the standard; then:

$$(2000\times n) \text{ yards on } \frac{2 \text{ ins.}}{1 \text{ mile Scale}} = 4000 \text{ yards on } \frac{n \text{ ins.}}{1 \text{ mile Scale.}}$$

Example. Required Scale $\frac{1}{50,000.}$ This is 1·267 ins. to 1 mile. Then $n=1{\cdot}267$.

Accordingly $2000\times 1{\cdot}267$ yds. on 2-inch Scale $=4000$ yds. on n-inch Scale.

That is 2534 yds. ,, ,, $=4000$ yds. on required Scale.

If more convenient, we can employ 3000 yds. instead of 4000 on the left side if we use double that amount (6000) on the right-hand side. Thus $3000\times n$ yds. on 2-inch Scale $=6000$ yds. on n-inch Scale.

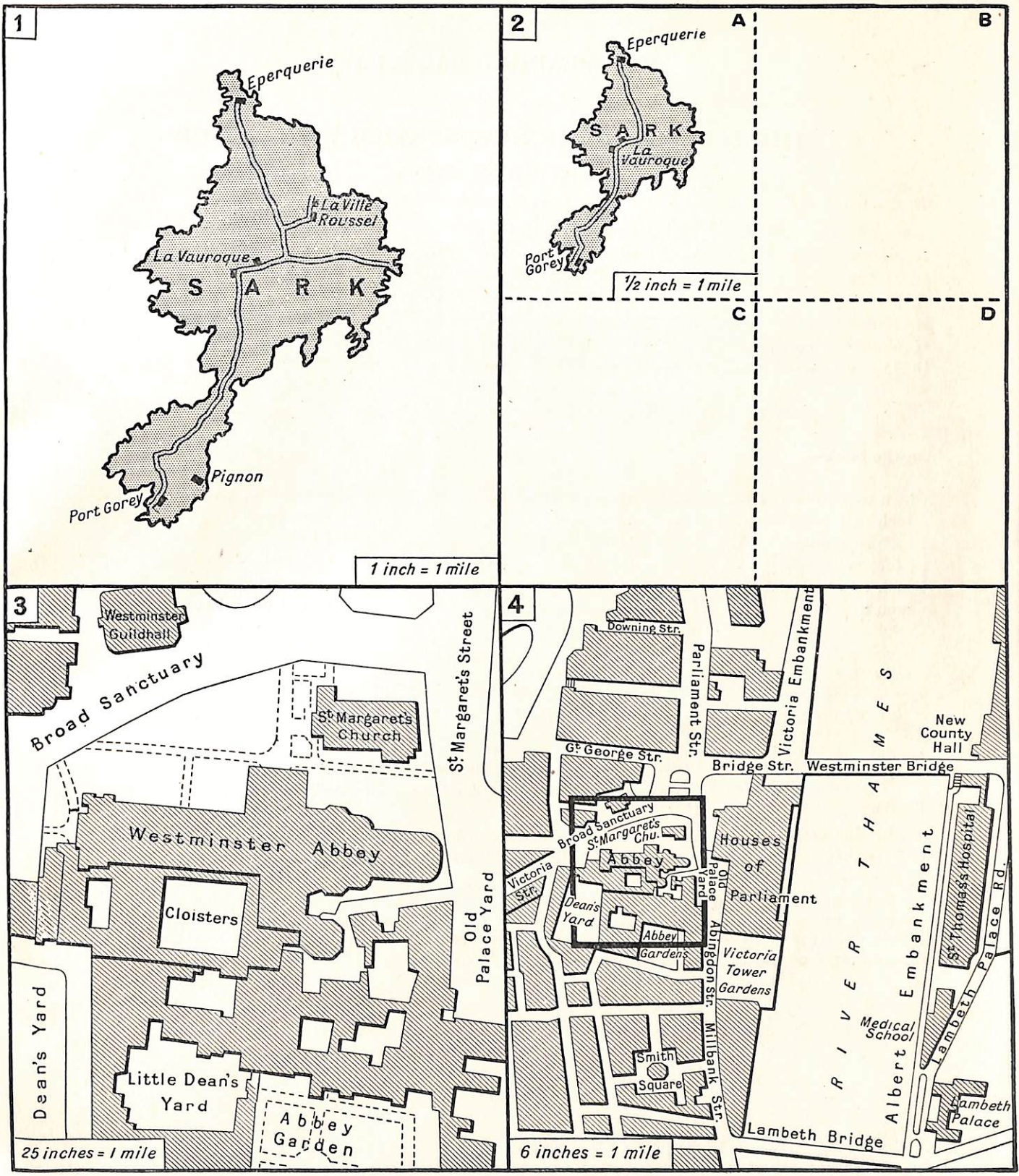


Fig. 107. Difference in Scale. Illustrating—(*a*) Area as in 1 and 2; (*b*) Area and Detail as in 3 and 4

THE SCALES ON THE NEW SERVICE PROTRACTOR

See Fig. 108 opposite.

On the front—

	Primaries.	*Secondaries.*
1: 50,000	1000 metres	100 metres
1: 25,000	500 metres	20 metres and 50 metres
1: 250,000	1 mile	$\frac{1}{4}$ mile
1: 250,000	5000 yards	1000 yards
1: 50,000	1000 yards	100 yards and 200 yards
1: 25,000	500 yards	20 yards, 50 yards and 100 yards

On the back—

	Primaries.	*Secondaries.*
1 inch to 1 mile	1000 yards	100 yards; 250 yards
$\frac{1}{4}$ inch to 1 mile	4000 yards	1000 yards
$\frac{1}{4}$ inch to 1 mile	1 mile	$\frac{1}{4}$ mile
1: 20,000	100 yards	20 yards
$\frac{1}{4}$ inch to 1 mile	4000 metres	1000 metres
1 inch to 1 mile	1000 metres	100 metres; 250 metres

The normal scales of British maps can be drawn from the Protractor.

Example. To draw a scale of 4 inches to 1 mile, to show divisions of 100 yards from the Protractor.

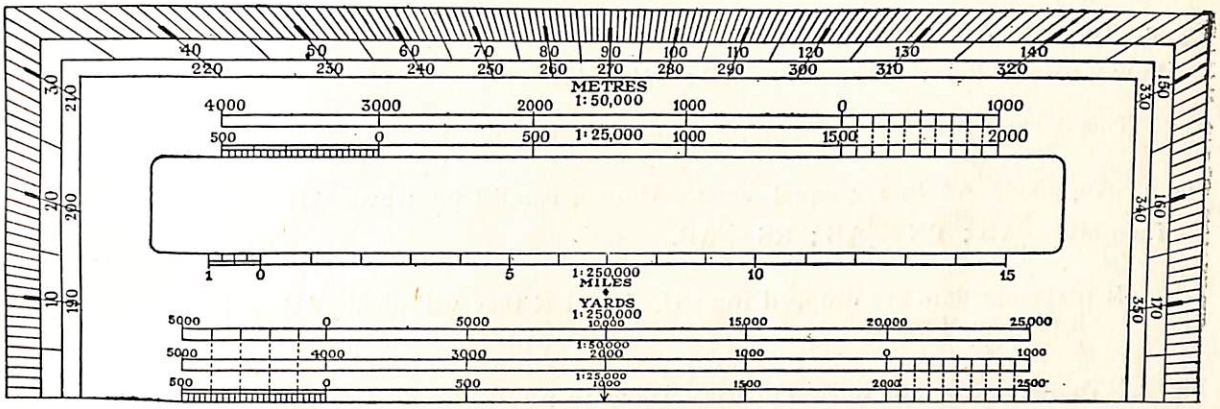
In this case the scale of 1 inch to 1 mile divided into 1000 yards divisions is the most convenient one to use. The distances shown on this scale are four times those on the scale which is to be drawn.

Draw a line equal in length to 8000 yards on the 1 inch to 1 mile scale; this line represents 2000 yards on the scale of 4 inches to 1 mile. Divide this line into four equal parts, giving the primary divisions of the scale, each representing 500 yards. Sub-divide the left division into five parts each representing 100 yards. These are the secondary divisions.

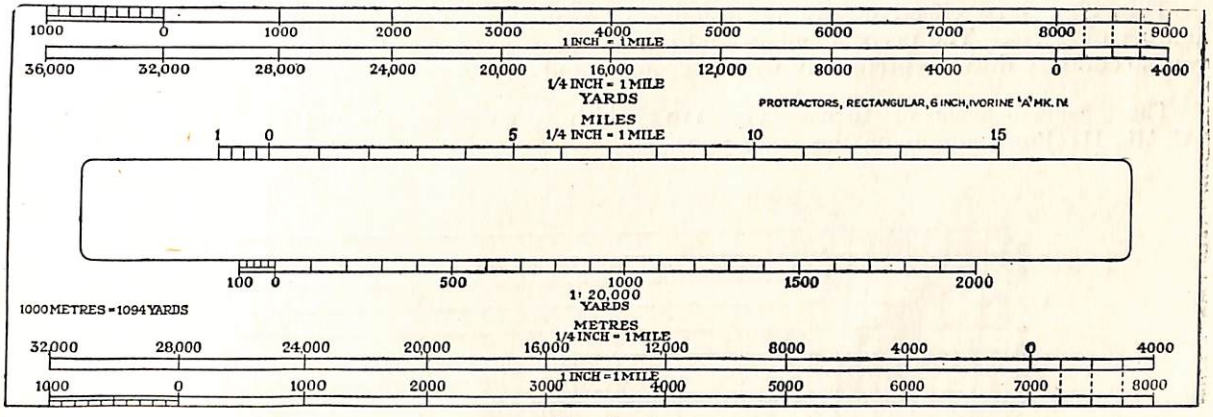
THE SERVICE PROTRACTOR

The latest type now in use (1941) is called the "A," Mark IV. It is rectangular and is made of ivorine, and is six inches long by two inches wide.

Below, both the front and the back of it are reproduced, showing the actual size, and the scales can be clearly seen.



The Front



The Back

Fig. 108

DIAGONAL SCALES.

A method of dividing a very short line into equal parts is by means of a diagonal.

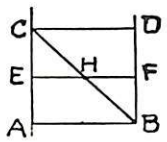


Fig. 1. To divide AB into 2 equal parts. Erect perpendiculars AC and BD and draw 2 parallel lines EF and CD above AB and at an equal distance apart. Join CB.

It will be quite evident that $HF=\frac{1}{2}AB$, so draw a perpendicular line to AB from H.

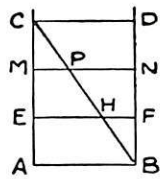


Fig. 2. To divide AB into 3 equal parts. Erect perpendiculars as before and draw 3 parallel lines. Then $HF=\frac{1}{3}AB$; $PN=\frac{2}{3}AB$.

This is evident by dropping perpendiculars from P and H.

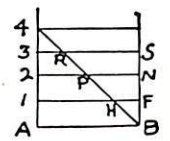


Fig. 3. To divide AB into 4 equal parts. Draw 4 parallel lines over AB. Then $HF=\frac{1}{4}AB$; $PN=\frac{2}{4}AB$; $RS=\frac{3}{4}AB$.

If perpendiculars are dropped from H, P and R they will divide AB into 4 equal parts.

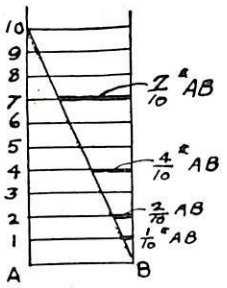


Fig. 109

Fig. 4. To divide AB into 10 equal parts. Draw 10 parallel lines over AB. Then the diagonal will cut the 9 lines between the top one and AB and give us $\frac{1}{10}AB$; $\frac{2}{10}AB$; $\frac{3}{10}AB$; $\frac{4}{10}AB$ up to $\frac{9}{10}AB$.

This is a very effective way of dividing a very short line into any number of parts. The perpendiculars and parallel lines must be of course very accurately drawn—preferably with a T square and a set square.

The Decimal Scale of Inches (Fig. 110), which is given on the old "A" Mk. III Protractor, is on the same principle.

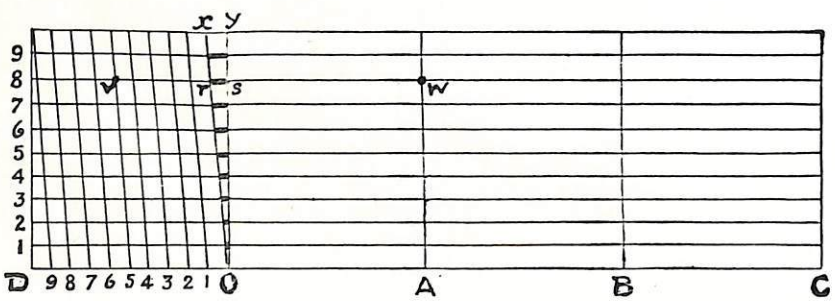


Fig. 110. The Decimal Scale of Inches

Referring to the *bottom line*, we have three Primary Divisions OA, AB, and BC, each equal to exactly 1 inch. DO is also 1″ and is divided into 10 Secondary Divisions, so that each division is $\frac{1}{10}$th of an inch. Thus OI (from right to left)$=\frac{1}{10}''$, 02$=\frac{2}{10}''$, 03$=\frac{3}{10}''$. Now $\frac{1}{10}''=\cdot1''$; $\frac{2}{10}''=\cdot2''$; $\frac{3}{10}''=\cdot3$, etc. Therefore we can from the bottom line get a measurement in inches of one decimal point.

Thus to take off a measurement of 2·7 inches, put one point of the dividers on B and the other on the point 7 in DO. Then we have got the length OB(=2″)+07 $\left(=\frac{7}{10}''\right)$. Total $2\frac{7}{10}''=2\cdot7$. Thus measurements with one decimal point are measured on the bottom line.

The other lines are for measurements of hundredths of inches—or two decimal points, by means of the diagonals.

The top line above DO is also divided into 10 equal parts like DO, and diagonals are drawn as shown. Take the first diagonal O*x*.

Since *yx*=OI, the diagonal crossing the 10 lines above 01 gives 10 equal divisions of OI.

Thus the short black lines over OI measure $\frac{1}{10}$th of OI, $\frac{2}{10}$th of OI, and so on.

Since OI is $\frac{1}{10}$ of an inch, these black lines measure $\frac{1}{100}''$, $\frac{2}{100}''$, $\frac{3}{100}''$, $\frac{4}{100}''$, etc., or ·01″, ·02″, ·03″, ·04″, etc.

Now suppose we want to take off a measurement of 1·58″. Put one right-hand point of dividers at A and the other at the 5th Secondary Division. This gives us a measurement of 1·5 ins.

Now count upwards along the diagonal line to the 8th horizontal line and at this point put one point of the dividers and open out the other point along the same horizontal line to the point where it meets the vertical line from A.

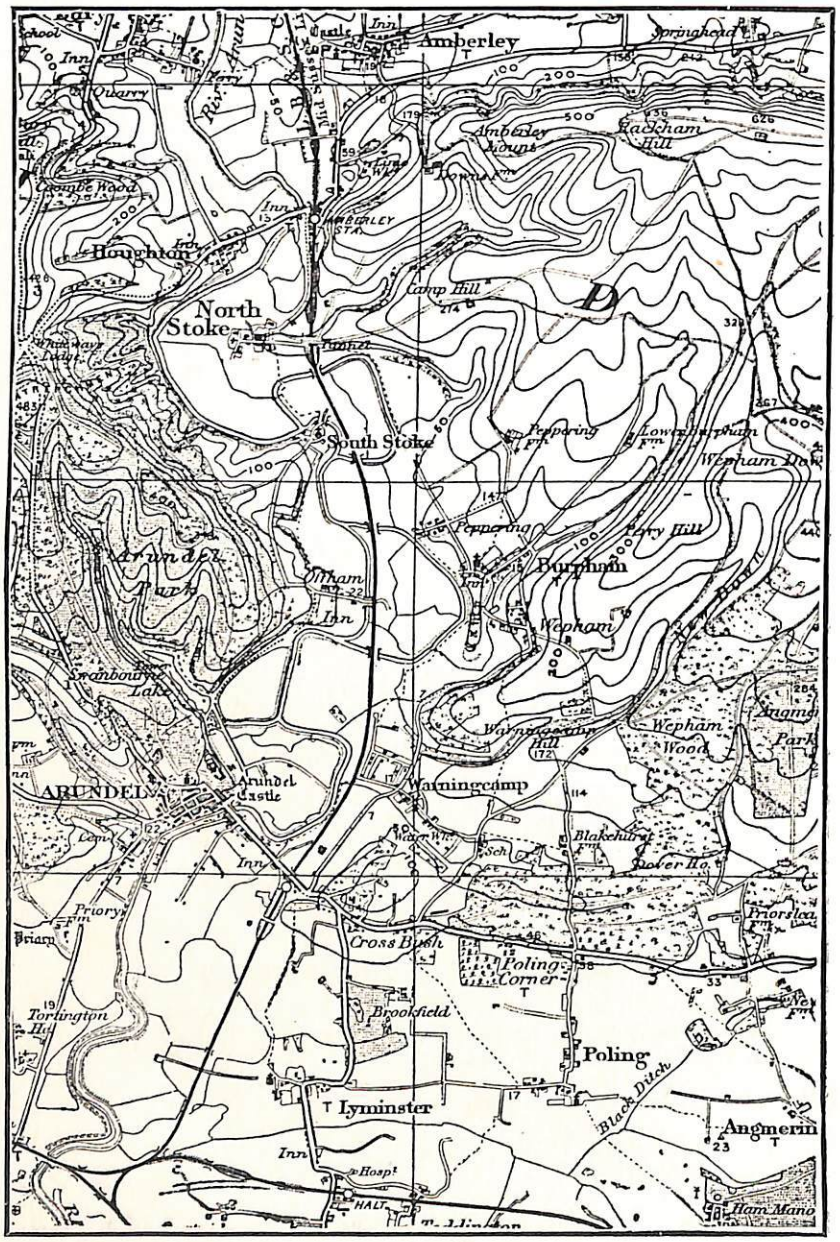
Then the distance we have got on the dividers is WV=1·58″. To show this is so,

$$\begin{aligned} WV &= WS+rv+sr \\ &= AO+O5+sr \\ &= 1''+\tfrac{5}{10}''+\tfrac{8}{100}''=1''+\cdot5''+\cdot08''=1\cdot58'' \end{aligned}$$

SOME USEFUL METRIC FIGURES

	Approximate
1 Metre=39·3708 Inches	= 3 Feet 3 Inches=1 Yard 3 Inches
1 Yard =00·914 Metres	
1 Kilometre (Km.)=1000 Metres	= $\frac{5}{8}$ Mile
=1094 Yards	
=0·621 Mile	
1 Mile=1·609 Kilometres.	5 Miles=8 Kilometres

The diameter of a half-penny is 1 inch.
The „ „ penny is 1·2 inch.



A portion of the One-inch Ordnance Survey Map of Great Britain.

(Reproduced from the Ordnance Survey Map with the sanction of the Controller of H.M. Stationery Office).

APPENDIX

HINTS ON DRAWING

Drawing a Straight Line. Hold the pencil *vertical*. If you don't hold it vertical, at least keep it at the same angle for the whole length. The pencil should be kept well sharpened.

For drawing fine lines a chisel point is the best, i.e. the pencil sharpened flat on two sides (see Fig. 112, which shows two views of it).

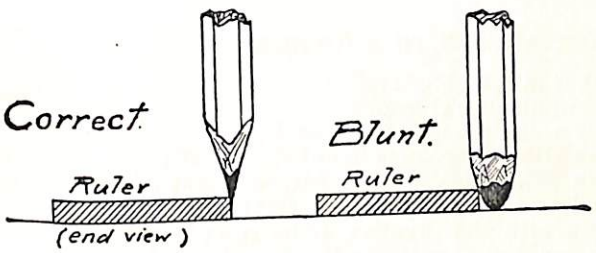


Fig. 111

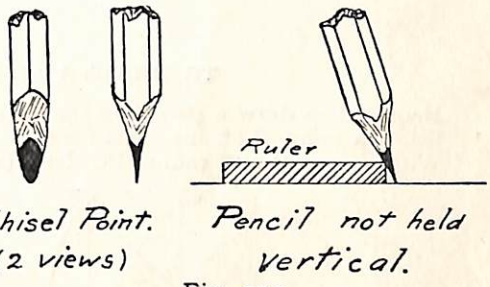


Fig. 112

Joining Points. Draw a *fine* line through the *centre* of the dots or points. Two badly drawn lines might make the difference of 1 or 2 degrees in a bearing.

Before drawing the line, after putting up the ruler, first test whether the pencil will pass through the centre of both points.

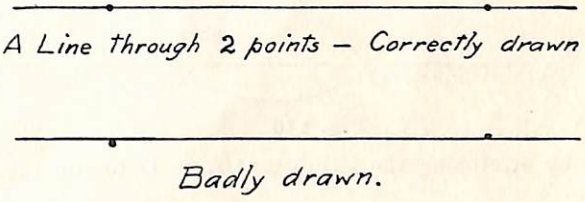


Fig. 113

Stepping off Distances with Dividers. Hold them between the thumb and first finger and rest the arm on the table. Suppose you start from A and B (Fig. 114), then turn the dividers round B (in the semicircle marked 1). Next turn the dividers round as in semicircle marked 2, but on the other side of the line, and so on—each side alternately. The reason for this is that if you turn them always on the same side you will have to keep on adjusting your hold, as they will otherwise twist right out of your hold.

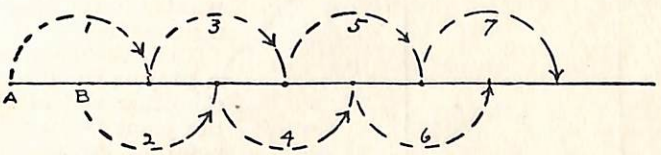


Fig. 114

The marks made by the points should not be too large or deep in the paper, especially if you are using ink afterwards.

Showing Measurements on Drawings. Put arrows at the end of the dotted lines, *exactly* opposite where the measurement begins and ends (Fig. 115).

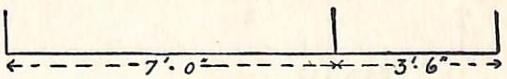


Fig. 115

INSTRUMENTS, ETC., FOR MAP READING

A Service Protractor. Made of ivorine and measures 6″ × 2″.
A Card Compass. Preferably a Prismatic.

A Pair of Dividers, preferably with an adjusting screw. If one point is placed at one end of the distance to be taken and the other point opened out as near as possible to the length required, the *exact* length can then be quickly obtained by means of the adjusting screw.

A Ruler with inches marked.

Pencils. A hard one, HH, for drawing lines, and a softer one, HB.

Pens. For very fine lines or small lettering, Gillott's Crow Quills are good.

Paper can be obtained ruled accurately both ways, into $\frac{1}{4}$″ (or $\frac{3}{16}$″ or $\frac{1}{8}$″) squares.

For copying maps or a part of a map, a transparent paper such as "Thin Bank" is very useful and has an excellent surface.

The following, of course, are extremely useful but can be done without: *Drawing Board, T Square, Set Squares,* and *Parallel Rules, Drawing Pen, A Pair of Compasses* (Pencil and Pen).

TO DRAW A LINE AT RIGHT ANGLES TO ANOTHER

Required to draw a perpendicular from the point C in AB (Fig. 116).
Select a point P at any distance and at an angle of about 45° from C.
With centre P and radius PC describe an arc of a circle cutting AB at D.

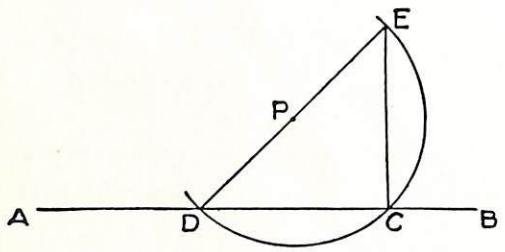


Fig. 116

Join DP and produce to cut the arc at E.

Join EC, which will be perpendicular to AB, because all angles in a semicircle are right angles. This could be done with the dividers, if no compasses were handy, as you can find D without drawing the arc and measure off PE equal to PD.

Note.—It may be a help to remember this diagram by noting its semblance to a boat leaning over with the gunwale on the water line.

This method is useful on the ground. By putting a peg in at P and using string you get D, where put another peg in and similar one in at E, which you find by stretching the string taut from D to run through P and measuring PE=PD (or PC).

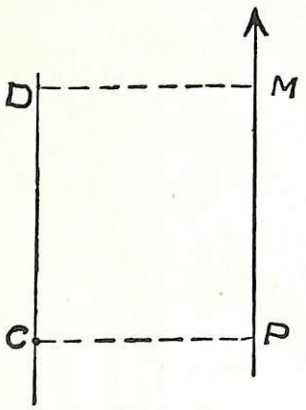


Fig. 117

TO DRAW A LINE PARALLEL TO ANOTHER

1. Without Set Squares. Suppose you wish to draw a line through C parallel to the Magnetic North line PM (which should be produced if necessary).

Take the distance CP (as near as you can judge at right angles to PM) on the dividers and then place one point of the dividers on the other end of the Magnetic North line, say at M, and make the point D (as near as right angles as possible) with the other point of the dividers. Draw a line through CD which will be parallel to PM.

(The measurement CP could be ticked off on a square piece of paper instead of using the dividers, one edge being laid along the North line to ensure CP being at right angles.)

2. Using a Set Square.

1. Place the long edge of a set square accurately along the line (*a*).
2. Then holding the set square steady, place a ruler (or another set square) along either of the other sides of the set square.
3. Now hold down ruler firm on the paper with left hand and slide set square with right hand along the ruler to required position (*b*).
4. Still holding ruler firm with thumb and two fingers of left hand, hold set square steady with the two other fingers and draw along the long edge of set square the line required. Take care to keep ruler steady and edge of set square pressed against ruler.

Note.—Several parallel lines can be ruled this way without shifting the ruler.

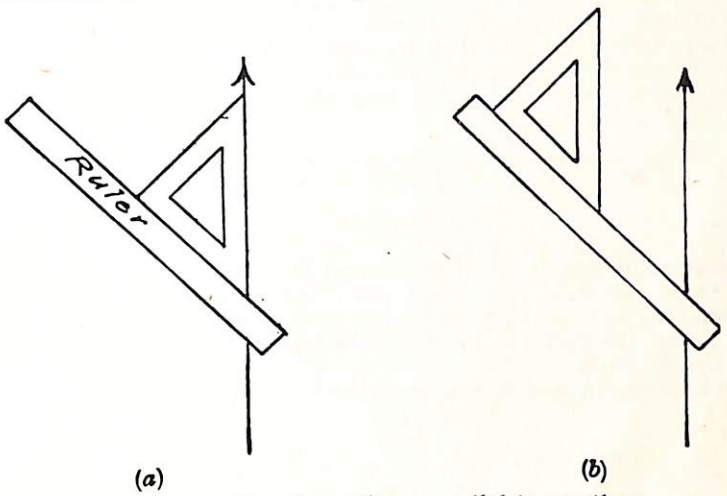


Fig. 118. Drawing a line parallel to another

In the diagrams below (Fig. 119) another example is shown, presuming the parallel line required to be drawn is lower down.

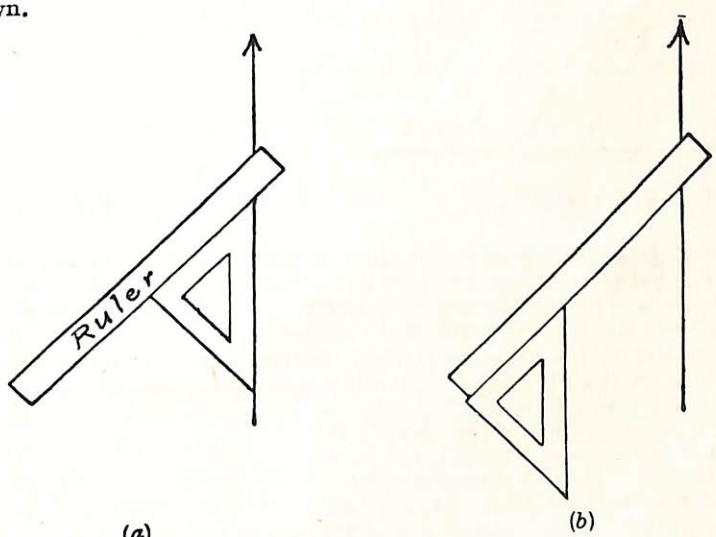


Fig. 119

TO DIVIDE A LINE INTO EQUAL PARTS

1. **If the line is a round number of inches**, and is a multiple of the number of divisions required, a foot rule can, of course, be laid along and the divisions marked off.

2. **By folding a strip of paper.** If the length of line is marked off on a strip of paper and the paper carefully folded in the centre, this will divide the line into 2. By folding again it would be divided into 4, and again into 8. If extreme accuracy is required, this would have to be checked by the dividers after transferring to your line on the map.

3. **By the Dividers.** Here you must first make a trial. Suppose you wish to divide the line AB in 3 equal parts. Estimate the distance—on the dividers—as near as you can and step it out 3 times, beginning from one end and make a slight mark where you finish. Suppose you are about ¼ inch too long (Fig. 120), then as this error is spread over 3 divisions, close the dividers a distance you judge to be a third of the error and then try again. You will find you are then very nearly right and by repeating the process you get the exact division. Similarly if dividing the line into 7 equal parts and you end up say about 2 ins. too long, close the dividers by what you judge to be one-seventh of 2 ins. and try again.

Fig. 120

4. **Draw a line at an acute angle** (about 30°) from one end of the line AB (Fig. 121) to be divided, say into 7 equal parts. Open the dividers to what you roughly judge to be ⅐ of AB, and step this off 7 times up AC, beginning from A. You end up at 7, then A7 is divided into 7 equal parts.

Join 7B and from the divisions on A7, draw lines to AB parallel to 7B, and these lines will divide AB into 7 equal parts.

This is a quick, accurate, and favourite method.

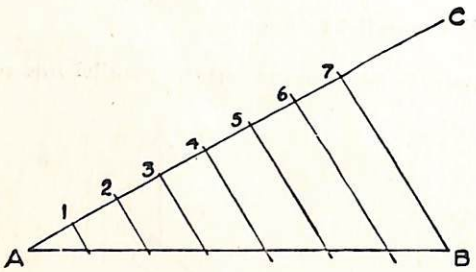


Fig. 121

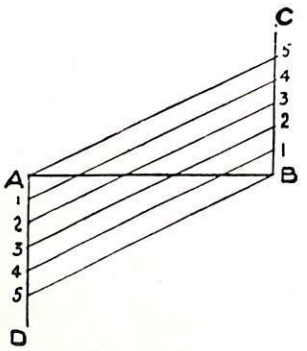


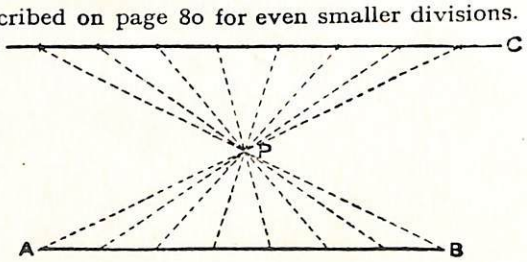
Fig. 122

5. **For very small divisions.** Draw 2 perpendiculars from each end (see Fig. 122) one above and one below; take a short distance on the dividers and step along each of these lines (beginning from A and B) the number of times as divisions are required (say 5). Join the points as shown, and the points where these lines cross AB are the required divisions.

Note.—This is similar to the diagonal method described on page 80 for even smaller divisions.

6. By using a Scale such as on the Protractor. Suppose you want to divide AB into 7 equal parts. Select a scale in which 7 divisions are about the length AB. Lay this scale on the paper parallel to AB and draw a line SC along its edge. Tick off 7 scale divisions.

Join AC and BS, meeting at P. AC and BS should roughly be at right angles. Draw lines from each of the divisions on SC through P to meet AB, and AB will be divided into 7 equal parts.



LETTERING

Anyone having to do with maps is soon bound to have occasion to put some wording on a map. For the sake of clearness and appearance the letters should be " printed out."

The Roman Alphabet (that used in ordinary type in books and newspapers) is the basis of nearly all types used. These letters take time to draw, though a thorough study of them is very useful.

For our purposes something simpler and quicker is required and this is found in *Single-stroke letters*—an alphabet of which is given below. There being a similarity between different lots of letters, they are shown in different groups.

After studying them and copying each one several times, try writing words and then correcting them. With a little practice, you will be surprised at the ease and quickness with which you can do them.

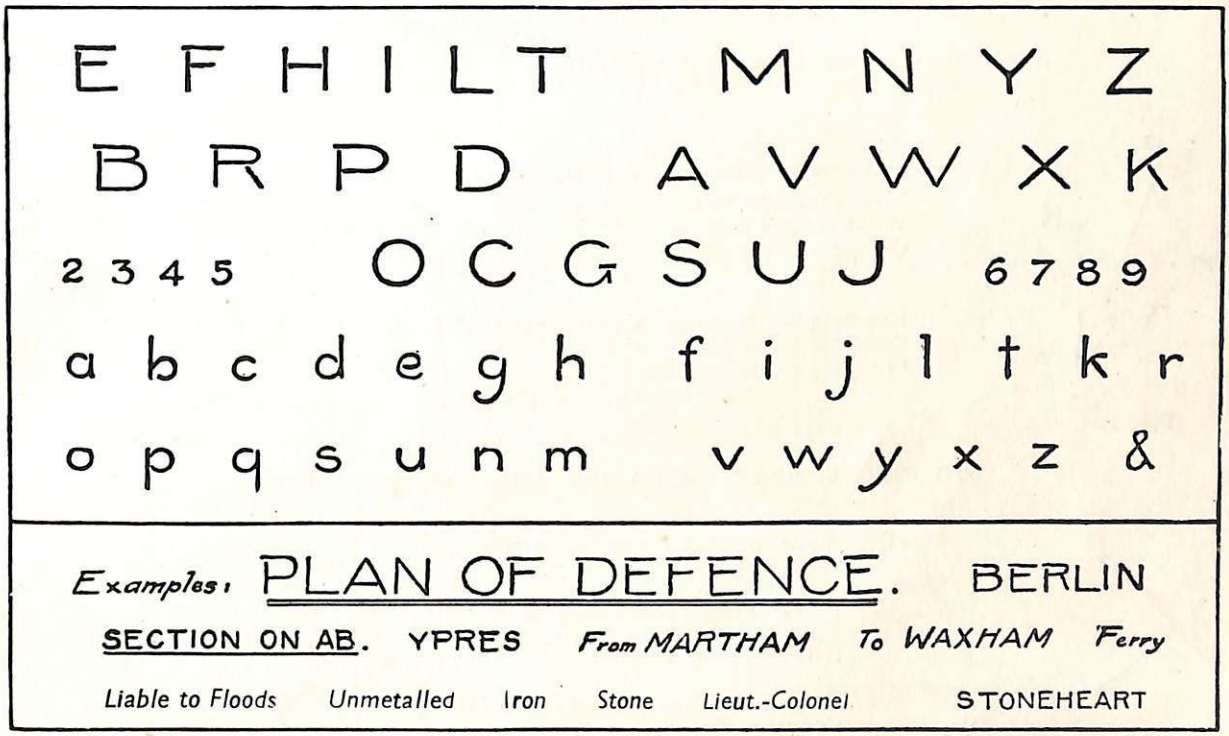

E F H I L T M N Y Z
B R P D A V W X K
2 3 4 5 O C G S U J 6 7 8 9
a b c d e g h f i j l t k r
o p q s u n m v w y x z &
Examples: PLAN OF DEFENCE. BERLIN
SECTION ON AB. YPRES From MARTHAM To WAXHAM Ferry
Liable to Floods Unmetalled Iron Stone Lieut.-Colonel STONEHEART

Fig. 123. Alphabet suitable for Map Work

Guide Lines. Rule 2 parallel lines lightly in pencil as a guide for the capitals. Rule another exactly half-way between these as a guide for the small letters. After a while you will find you can dispense with the guide lines, although it is as well always to use them for headings.

Pen. Use a stub pen—held in ordinary way for writing.

Draw the letters broad, if you have room, for clearness.

Keep the letters close together. Letters should not be all exactly the same space apart, but should *appear* to be. A capital I between an H and M would want extra space.

Leave plenty of space between words.

E, F, H, B, R (caps). Note the cross-bars are *above* the centre line.

S. The top half should be smaller than the bottom half.

A Circle is the foundation of many letters, e.g. a, b, c, p, n, etc.

Towns and Villages and Headings should be given in BLOCK letters (caps) to the right of the spot, unless there is no room.

Descriptive Notes on maps should be in italics, i.e. caps and small letters.

Sloping type can be used equally as well as vertical.

COMPASS ERROR

Magnetic Variation is the variation of a *true* compass from True North.

Compasses are often not quite true owing to some slight defect in manufacture or through wear and tear. The error is known as so many degrees East or West, i.e. East or West of the correct Magnetic North.

Suppose you are standing at the point C. CN is True North. CM is Magnetic North. If your compass were true it would point in the direction CM. If, however, it pointed in the direction CP, your Compass Error would be the angle PCM West of Magnetic North.

In this case the Compass Variation = Mag. Var. + Compass Error
= MCN + PCM

Always draw a rough diagram if in doubt.

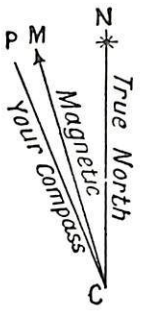


Fig. 124

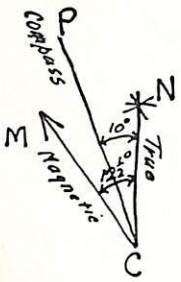


Fig. 125

Example 1. Magnetic Variation is 12½° West.
Your Compass Variation is 10° West.
What is the Compass Error ?
Compass Error = MCP = MCN – PCN (Fig. 125)
= 12½° – 10° = 2½° E.

Example 2. Magnetic Variation is 12½° *East.*
Compass Variation is 15° East.
Compass Error = MCP = NCP = NCM (Fig. 126)
= 15° – 12½° = 2½° E.

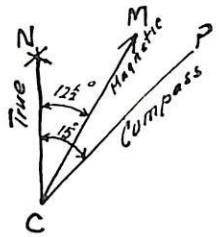


Fig. 126

TO FIND COMPASS VARIATION AND COMPASS ERROR

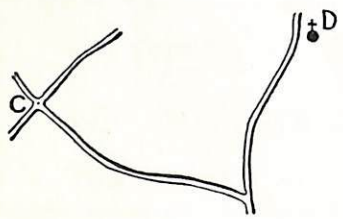


Fig. 127

You are standing at the cross roads at C and can see a distant church spire D (Fig. 127).

1. **From your map** find the True Bearing with Protractor, say it is 80° (Fig. 128).

2. **On the ground** take the Compass Bearing of D. Say you find it to be 97°.

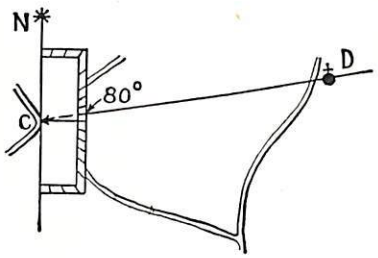


Fig. 128

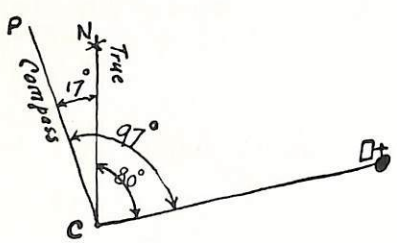


Fig. 129

3. **Draw a rough diagram** showing both True and Compass Bearings. Then your Compass Variation = PCN = 97° – 80° = 17° W (Fig. 129).

4. **Draw another rough diagram,** knowing Magnetic Variation = say 15° W., the Magnetic North line (CM) will come between CP and CN. Then Compass Error = PCM = PCN – MCN = 17° – 15° = 2° W., **i.e. West of Magnetic North** (Fig. 130).

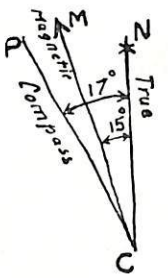


Fig. 130

AN EXAMPLE OF FINDING YOUR COMPASS BEARING FROM A MAP—ALLOWING FOR COMPASS ERROR

You have a map of a hilly country and want to get from the spot C to the distant spot D—cross country. The map shows True North and Magnetic North lines, and tells you the Magnetic Variation in 1912 was $16\frac{1}{2}$° W and the annual decrease is 5 minutes. Imagine it is now 1918. Your compass has a Compass Error of 2° East. What would be your Compass Bearing of D from C?

In this case you have to first find the True Bearing from the map with the Protractor, by drawing a line through C parallel to True North and joining CD and reading the True Bearing where CD cuts the edge of Protractor. Say in this case 41° (Fig. 131).

Now the Magnetic Variation has decreased 5′ (minutes) annually since 1912 (6 years ago), so that the total decrease to present time is 5′ × 6 = 30 minutes or $\frac{1}{2}$°.

The Magnetic Variation was $16\frac{1}{2}$ W. in 1912, so that in 1918 it is $16\frac{1}{2}° - \frac{1}{2}° = 16°$ W.

Now your compass having an error of 2° East (i.e. 2° East of Magnetic North), your *Compass* Variation will be 14° West of True North (Fig. 132).

You have found the True North Bearing to be 41°. Therefore your Compass Bearing of D from C would be 41° + 14° = 55° (Fig. 133).

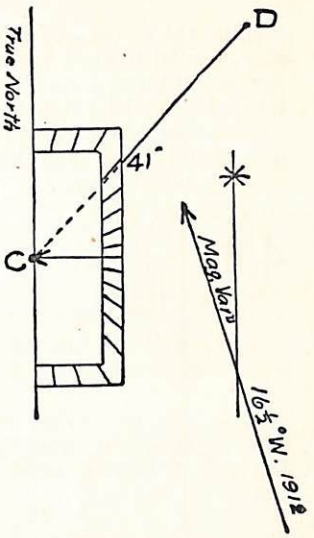


Fig. 131

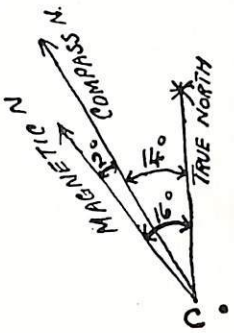


Fig. 132

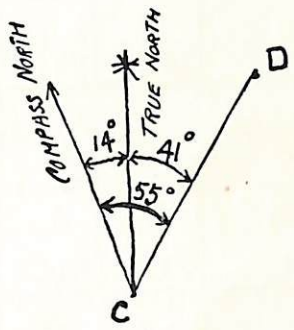


Fig. 133

REFERRING TO A PLACE ON THE MAP

1. **The Graticule.** Most atlases, in the index, give the latitude and longitude. These lines are called the *graticule*, and are drawn across the map (or marked on the margin) at various intervals and are numbered (in degrees). The place will be found where these imaginary lines cross.

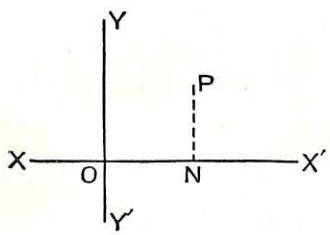


Fig. 134

2. **The Grid.** It is necessary on military maps to find a quicker and more accurate method of referring to a place, and this is supplied by the *Grid*. The basic principle is as follows:—

In Fig. 134 two lines, XOX′ and YOY′ are drawn at right-angles crossing one another at O, and if the position of O is known the position of point P can be described by the lengths of ON and NP (where NP is perpendicular to XOX′ or parallel to YOY′).

In all systems XOX′ is an east-west line and YOY′ a north-south line, and ON and NP are termed *eastings* and *northings* respectively.

Gridded maps are divided up into squares by lines running north-south and east-west, and the south-west (or bottom left-hand) corner of each square corresponds to the point O (Fig. 134). From this point references are given.

Fig. 135 shows one of the large 10-kilometre grid-squares as used in the old British System—reduced in size in order to show the numbering. This square is lettered *D*, and any reference for a place in this part of the map is given from the left-hand bottom corner of this square. This large square D (thick lines) is divided into a hundred 1-kilometre squares by fine lines which are numbered.

Suppose you are given the reference D 8, 6; this would mean that the point is found by counting the eighth line eastward and then the sixth line northward—as shown at the corner of one of the small squares.

Now take the point *p*. This is five lines and a bit eastward and three lines and a bit northward. You can

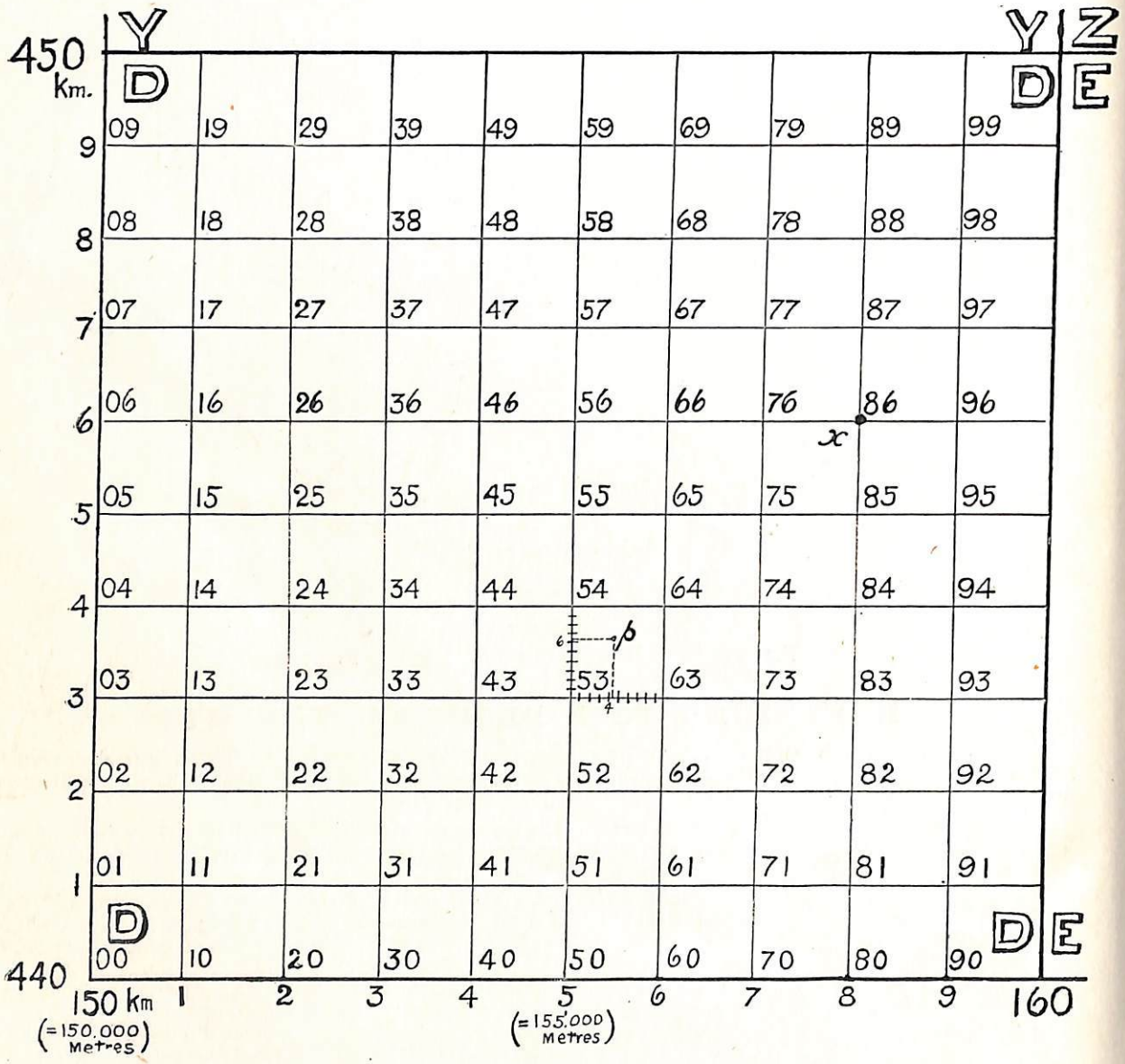


Fig. 135

judge by the eye that it is five and about $\frac{4}{10}$ths eastward and three and $\frac{6}{10}$ths northward, so the eastings are 54 and the northings 36. The map reference is D 54, 36. To be more precise still, as the point *p* is a shade more east and a shade more north—$\frac{41}{100}$ and $\frac{62}{100}$ the map reference may be given as D 541,362 or D 541362.

By using kilometre squares advantage is taken of the decimal or metric system; as a matter of fact the point *p* is 541 metres east and then 362 metres north of our measuring point, but there is no need to bother about the distances, the idea being to enable one to locate a spot on the map quickly, or conversely to give the reference of a known spot.

The Modified British System, now in use on all military editions of maps of Great Britain differs in the lettering of the squares. These two rules apply to both systems:—

(a) Easting comes first, northing second.

(b) The same number of figures must be given for both easting and northing; thus the reference will always be an even number of figures; the first half being easting and the second half the northing.

In the Modified British System the area is divided into squares of 500 kilometres side, each of which is designated by a letter. In Fig. 136 it will be seen that squares Q, R, V and W easily cover the whole of England.

Each of these squares is subdivided into twenty-five squares of 100 kilometres side, which are also lettered A to Z, omitting letter "I." These squares are again sub-divided, each into 100 squares of 10 kilometres side.

To avoid confusion, the letters for both the 500 kilometre square and the 100 kilometre square should be quoted when a map reference is given, e.g. BLANDFORD FORUM: v U 3227. A six-figure reference should be given for the precise location of smaller places.

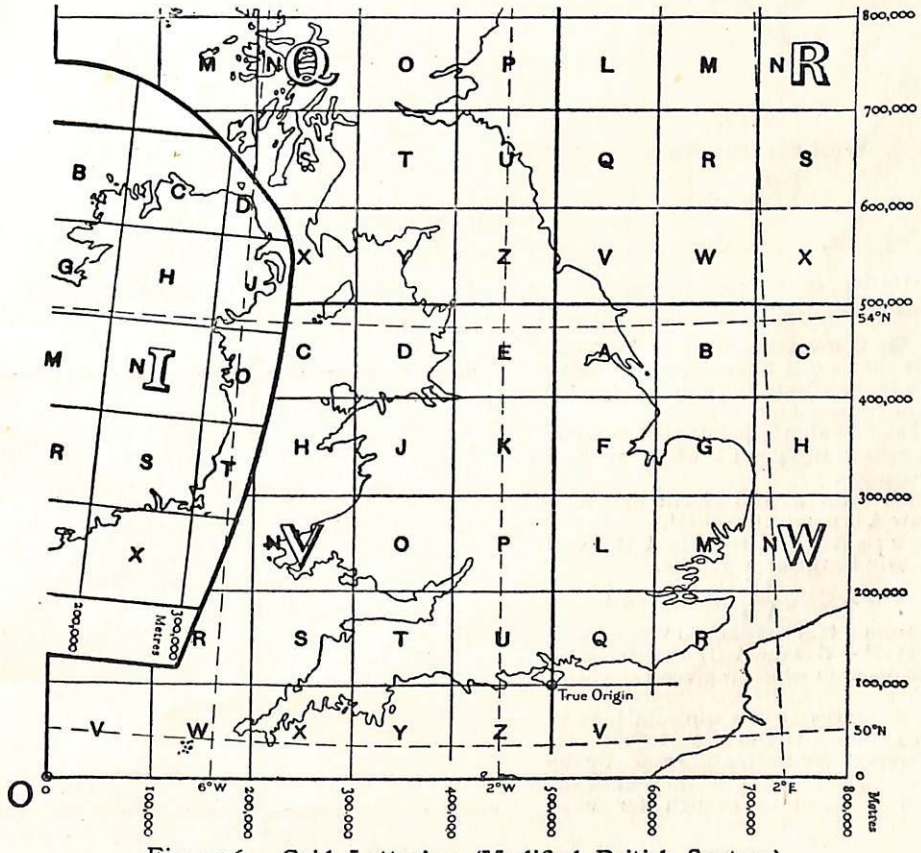


Fig. 136. Grid Lettering (Modified British System)

(Reproduced from the MANUAL OF MAP READING, PHOTO READING AND FIELD SKETCHING, with the sanction of the Controller of H.M. Stationery Office).

In Small Scale Maps (10 miles to the inch and $\frac{1}{4}$ inch to the mile) the sides of each 100-kilometre square are thickened; the appropriate letter in the middle of the square, and to the left of it is printed, also the letter of the 500-kilometre square in which the 100-kilometre square falls. The left-hand bottom corner of the 100-kilometre lettered square is the point to which the map reference is normally referred. There is a certain amount of numbering of the grid lines to assist in reading the reference.

In the One Inch to One Mile and Larger Scale Maps the ten-kilometre squares are again divided into 100 squares of one-kilometre side, and all these grid lines are numbered. The sides of the ten-kilometre squares are thickened.

On this scale map, since there is no possibility of duplication, the letters referring to the 500-kilometre and 100-kilometre squares are omitted from the grid. A small diagram on the map margin indicates the letter (or letters of the 100-kilometre square (or squares) in which the particular sheet lies.

Grid North and True North. The vertical grid lines are "Grid North." These will be True North around our Original axis on Salisbury Plain, but the True Meridians converge toward the Pole West and East, and it is sometimes necessary to convert from Grid to True North and vice versa.

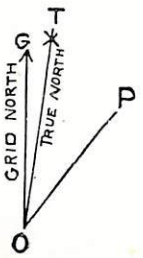


Fig. 137
West of True Axis

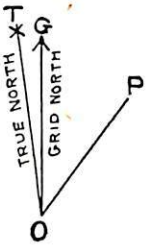


Fig. 138
East of True Axis

Angle of Convergence	= GOT
Grid Bearing of P from O	= GOP
True Bearing of P from O	= TOP

In converting, in one case you add the angle of convergence, in the other you subtract.

The maximum deviation in the extreme Eastern or Western Counties is not more than 4°.

To calculate the Convergence from a large scale map like the new 1/20,000 of England, which shows the points where the graticule (longitude) cuts the top and bottom of the sheet:–

In Fig. 140 G and G^1 are the points of the nearest graticule on the map to the point P where we want to find the convergence.

Join G G^1 and draw a Grid North line A B through P. Draw A C paralled to G G^1.

This will give a right-angled triangle A B C and B A C will obviously be the convergence.

The tangent of B A C $= \frac{B\,C}{A\,B}$ which can be accordingly taken from a table of natural tangents.

Now B C = B G^1 – C G (or A G) so there is no need to draw the diagram which is given to explain the following rule:–

Measure the distances at the top and bottom from the nearest meridian to the nearest Grid Line and take the difference; divide this difference by the depth of the sheet. The result is the tangent of the Convergence and is accurate enough for most purposes.

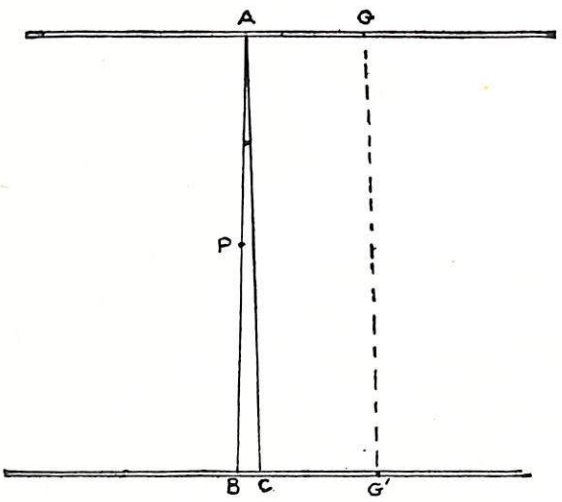


Fig. 139

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